STRUCTURE, GENERAL CHARACTERISTICS, AND SALINITY RELATIONSHIPS OF BENTHIC MACROINVERTEBRATE ASSOCIATIONS IN STREAMS DRAINING THE SOUTHERN FORT UNION COALFIELD REGION OF SOUTHEASTERN MONTANA

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ABSTRACT

The State Water Quality Bureau has completed a two-year biological-benthic inventory of streams draining the southern Fort Union coalfield area in southeastern Montana and a small part of northern Wyoming. Attention was directed primarily to the benthic macroinvertebrate taxa and the periphyton communities that are found in the study region, and this report relays the results of the faunal component of the project. It describes existence of a fairly diverse, generally healthy, variable, and highly dynamic set of benthic macroinvertebrate associations in these waters. Moderate levels of environment stress were identified in some of the streams, and salinity appears to be one of the factors that influences the faunal communities from a diversity standpoint, although this parameter does not affect the total abundance characteristics of these organisms to a significant degree. Since salinity enhancements are conceivable from future coal mining activities, this observation is also of some importance from a land management perspective. In addition to these salinity considerations, the report also describes the structure, faunal composition, seasonal changes, habitat preferences, and general characteristics of the macroinvertebrate associations and benthic animals that inhabit the rivers and creeks of this coalfield region, and these discussions, thereby, fulfill the basic inventory objectives of the southern Fort Union project.

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURE

INTRODUCTION

This report is one part of a trilogy that presents the findings that were obtained from a biological-benthic study of streams draining the southern Fort Union region of southeastern Montana. The southeastern portion of the State contains large quantities of strippable coal deposits, and as a result, this section of Montana is expected to receive some level of water quality impacts from future coal mining activities. The general lack of biological information for small streams in this coalfield region prompted the Water Quality Bureau (WQB) of the Montana Department of Health and Environmental Sciences to seek funding by which to undertake a hydrobiological inventory effort for the area. The proposed study was subsequently funded as a two-year field project by the United States Geological Survey (USGS) and the Bureau of Land Management (BLM) under USGS Research Grant Number 14-08-0001-G-503.

This writing is intended as an interpretive report that deals specifically with the faunal macroinvertebrate organisms that were collected from the Fort Union streams, and a companion publication (Bahls, 1980) considers the periphytic-algal components of these same waters. The third report of the trilogy (Klarich, et al, 1980) was developed as a data compilation that presents most of the biological, physical, and water quality data that were secured during the project, and it thereby acts as an appendix for the two interpretive presentations. These three reports represent the final requirement of the study. Other writings associated with the project are the initial research proposal (Klarich, 1977), and a second-year continuation proposal (Klarich, 1978), and an interim report (Klarich, 1979).

The basic objective of this inventory was the accumulation of a relatively extensive hydrobiological data base for the coalfield area streams that could be used for future reference purposes as coal mining continues and accelerates in the region. The objective of this particular report, in turn, is to adequately characterize and describe the benthic macroinvertebrate associations of these waters as revealed by the project collections. Judgements pertaining to the general biological quality of the study area streams will also be made as a part of these descriptions.

As a second objective of the study, an attempt will be made to elucidate any possible effects of stream salinity on the benthic macroinvertebrates along with a general discussion concerning the relationships between these organisms and this important water quality variable. Such an application is a feasible component of this project because of the fairly wide range of differences in salinity levels that are found among the different southern Fort Union streams. Considerations of this kind are important because elevated salinity concentrations are projected to occur from the increased coal mining activities in the region. Furthermore, salinity is of added consequence for this area and for the State of Montana as a whole since the impacts that are derived from this parameter can arise from other sources besides strip mining such as the development of saline seep and the occurrence of irrigation return flows. The action of salinity as a potential affecting factor in the study area waters has also been rather extensively reviewed in the algal report that

is a companion presentation to this writing (Bahls, 1980).

DESCRIPTION OF THE STUDY AREA

Figure 1 presents a generalized map of the southern Fort Union study area of the project. This region is located within the Yellowstone River basin of southeastern Montana and extreme north central Wyoming, and as illustrated by the figure, a major portion of the sampling took place within the Rosebud Creek and Tongue River drainages. Both Rosebud Creek and the Tongue River are relatively large tributaries to the Yellowstone River, and a few of the smaller creeks such as Sarpy Creek that are direct tributaries to the Yellowstone were also sampled during the course of the study. All of these streams drain lands to the south of the Yellowstone River so that the mainstem delineates the northern border of the study region. Except for the lands associated with a few streams sampled in Wyoming, forming the small southwestern "hump" of the project map, the Montana-Wyoming state line affords the southern boundary of the inventory area. The western border is formed by parts of the western Sarpy Creek, Rosebud Creek, and Tongue River divides, and since a few sampling stations were also located in the Powder River drainage, the eastern divide of this system denotes the extreme eastward extension of the sampling program. The study area thereby encompasses about 11,000 square miles, and it includes parts of six Montana counties (Treasure, Rosebud, Custer, Prairie, Big Horn, and Powder River) and a small segment of one county in Wyoming (Sheridan).

Figure 1 denotes the locations of the different sampling sites utilized during the inventory. These sites will be considered in more detail in the next chapter of this report, and this will include a referencing of the numbers on the map to particular streams and stations.

SAMPLING PROGRAM

GENERAL CONSIDERATIONS AND RATIONALE

In viewing aquatic systems such as the streams of the Fort Union study region, the layman's attention is most commonly focused upon the fishery potential of a water because of the economic importance of this group of organisms as food items and as recreational targets through sport fishing. But in an ecological sense, numerous other types of non-fish organisms that inhabit the same water are equally or more important than the fishery *per se* in terms of maintaining the integrity, balance, and functions of the system. For example, the smaller floral and faunal elements comprise particular parts of the food chains and food webs that ultimately afford sustenance to the fish, and the proper operation of these food chains and webs is essential for the occurrence of productive and reproducing fish populations. The algal-periphytic component of such chains and webs act as the primary producers of a water, i.e., the initial food synthesizers, while the macroinvertebrates act as energy transfer agents from this initial producing level to the different vertebrate forms, such as the fish, that depend upon the water. As a result, data that describe the algal and macroinvertebrate groups provide important insights into the nature, characteristics, and health of the entire system, and this then affords the basis for undertaking the coalfield aquatic inventory

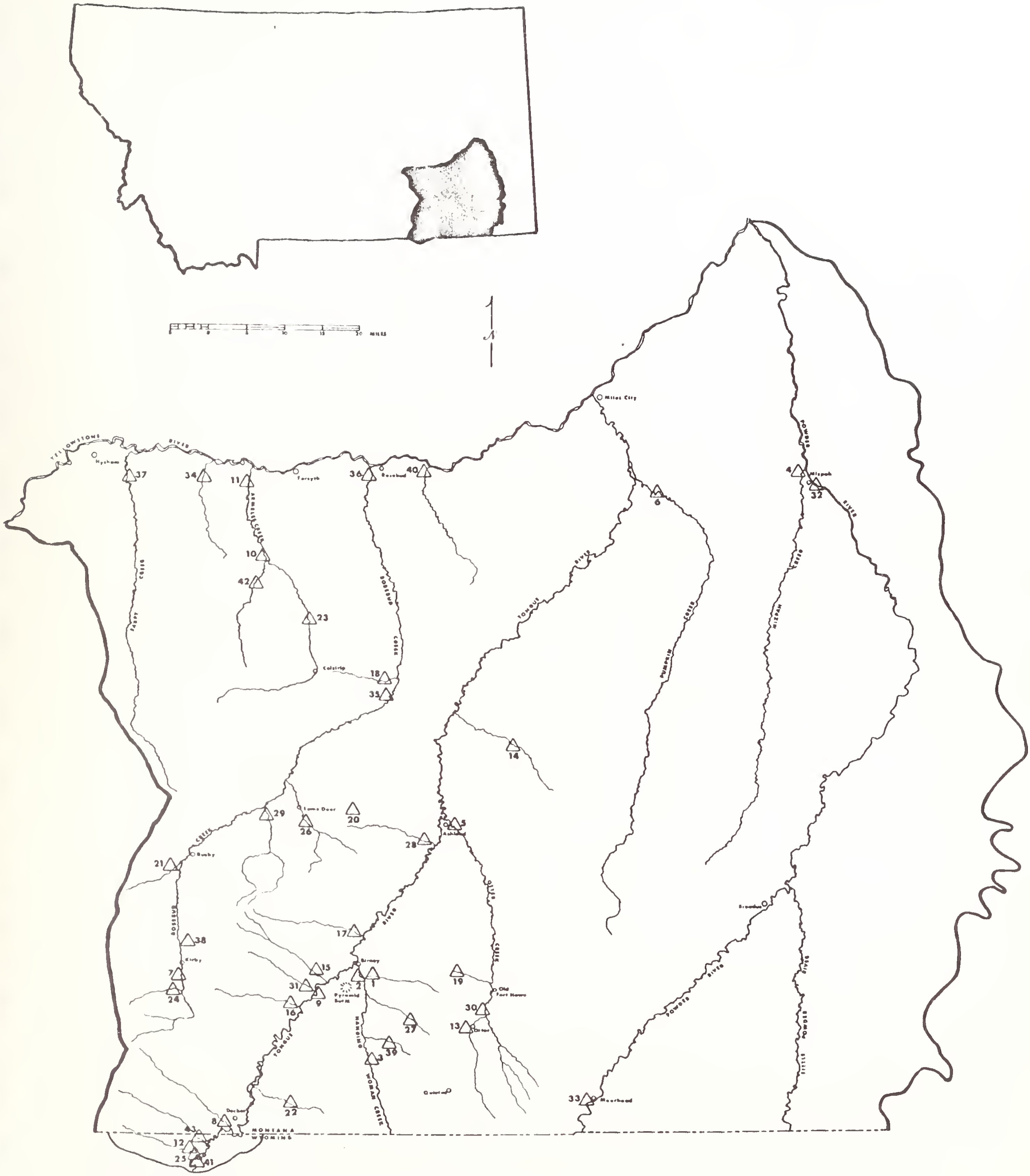

Figure 1. Map of the southern Fort Union study area in Montana and a small part of Wyoming showing the locations of the various sampling stations.

that is considered in this writing and its two companion reports.

The benthic macroinvertebrates which provide the focus of this particular report are defined as those invertebrate organisms that are retained by a United States Standard Number 30 sieve and that spend all or at least a part of their life cycles living within or upon the bottom substrates of a stream, pond, lake, or sea (Weber, 1973). These invertebrates, though often quite small, can be seen with the naked eye; the smaller invertebrates that are not retained by a Number 30 sieve are classified as microinvertebrates, and these organisms were beyond the scope of this investigation. Substrates that "house" the benthic macroinvertebrates are the fine sediments, the sands, gravels, and rocks, the submerged logs and other kinds of debris, and the living aquatic macrophytes (large, submerged vascular plants) and macroalgae that might be found at the bottom of a body of water. Some of the aquatic macroinvertebrates, however, do not permanently occupy these substrates, and such nektonic, neustonic, and littoral types of organisms were not directly included into the main sampling program of this project, although some of these non-benthic forms were inadvertently collected as "visitors" during the bottom sampling procedures.

The benthic macroinvertebrates of most freshwaters consist of members of the insect, mollusc (snails, mussels, and clams), annelid (segmented worms), crustacean (seed shrimp, scuds, and crayfish), turbellarian (flatworms), and nematodal (roundworms) groups that are observed in varying proportions and abundances in different aquatic habitats. Insects are often the most important of these wide categories and they are typically present in a water in their immature or larval stages with the emergent adults terrestial in nature. But some of the benthic insects do complete their entire life cycles in the water, and the other benthic groups are also generally fully aquatic in character.

The many kinds of benthic macroinvertebrates that can be typically collected from streams and ponds perform a number of different roles within these systems, and such organisms thereby fill a variety of aquatic niches and assume an assortment of ecological professions. These professions are broadly described as the detritus feeders, the grazers and herbivores, the scavengers, the parasites, the predators and carnivores, and the omnivores. Since efficiently functioning aquatic systems generally prescribe a wide range of ecological niches, most biologically healthy streams and ponds should demonstrate a relatively high number of different macroinvertebrate types or taxa filling these niches in relation to the total number of macroinvertebrate individuals that might be found within any particular habitat. In unstressed systems, a few of the taxa, commonly the grazers and herbivores, show a fair level of abundance while not being overly dominant, while other taxa reveal a more moderate level of abundance with still other taxa, often the predators, showing only a few individuals per unit area. This form of community organization is generally described by MacArthur's (1957) broken stick model where a few of the taxa are relatively abundant but with an increasing number of the taxa having fewer and fewer individuals (Weber, 1973). Healthy systems that follow MacArthur's model, thereby, possess a high degree of taxonomic or biological diversity. However, if an excessive

environmental stress of some kind is applied to the system, such as an input of organic or toxic pollution, this picture tends to change, and the recognition of any variations from the normal case in the structure and organization of the benthic macroinvertebrate associations can be used as a research took by which to judge the general biotic health of a water.

All of the macroinvertebrate taxa have particular levels of sensitivity to different kinds of environmental stress, and since this is a differential tolerance that depends upon the characteristics of the organism and the magnitude of the affecting factor, more and more of the organisms that are highly sensitive to the factor begin to gradually disappear from the system as the intensity of the stress begins to surpass their tolerance limits in a sequential fashion. Stress, therefore, acts to cause a reduction in the number of taxa that are present in the affected stream or pond, and this decrease in the number of taxa produces a decline in biological competition. In the extreme case, no organisms would be present at high stress levels above a maxiumum tolerance limit with a complete absence of biological competition. In less severe instances, a drop in competition allows a set of more tolerant macroinvertebrates to greatly increase in abundance so that the total numbers of organisms that are present in an affected system do not necessarily have to decline to any significant extent. The ultimate denouement of these changes is a deviation in community structure from MacArthur's unstressed model to the case where a few tolerant taxa are markedly abundant and dominant with the other taxa absent or rare. As a result, unhealthy aquatic systems have a low ratio of taxa numbers to total individuals, and such benthic macroinvertebrate associations demonstrate a low level of biological diversity. With the occurrence of a low diversity, some type of environmental difficulty might be assumed for the system.

The differing sensitivities and tolerances of the macroinvertebrate taxa to different types of stress can be used in a limited manner as a means for assessing the conditions of an aquatic system. Such evaluations hinge on the postulate that the presence of a sensitive taxa or particular indicator species requires the absence of the associated affecting factor. However, the converse is not true: The absence of an indicator species does not indicate the occurrence of a given stress since the void of a species could be due to the action of other factors rather than the stress *per se*. Furthermore, the presence or absence of tolerant species is of no diagnostic value since these organisms can occur in both clean and polluted or impacted waters. This then points to the weakness of the indicator species approach, although it does have some applications under defined conditions.

A more useful and meaningful diagnostic option in relation to the precepts developed in the previous discussion is the use of macroinvertebrate diversity as an indicator of environmental stress. This application is enhanced by the fact that mathematical means are available by which to quantitatively express the diversity of a system if the appropriate data are at hand. At least in a theoretical sense, an inverse relationship should exist between a diversity measurement and the magnitude of the stress, and such diversity indices would be expected

to be lower as the extent of the affecting factor increases. Thus, diversity assessments can provide some insight into the amount of stress that is impacting a system as well as afford a confirmation of its occurrence or non-occurrence in a body of water. Such applications have been most typically made in relation to obvious point sources of pollution such as wastewater treatment plant and industrial effluents in order to ascertain the actuality and degree of an instream effect. But this same approach can be used with reference to more subtle pollutive influences such as elevated salinity and sediment levels from non-point sources, and it also can be used in unpolluted instances to judge the biological health of a water in the face of environmental stress from natural sources. Because of these latter two features, such diversity assessments formed the focal point for the data reductions, analyses, and interpretations that were developed for the coalfield inventory.

Aquatic benthic macroinvertebrates have other inherent characteristics that make their use as an investigative tool additionally applicable and meaningful. Since these organisms are relatively immobile and long-lived, they serve to integrate the effects of environmental problems and water quality degradations over a fairly long period of time. Thus, the characteristics of a benthic macroinvertebrate association at the time of collection are a function of the conditions that were in operation during the past several months, and this aspect is of value from an interpretive standpoint. In addition, since these benthic organisms are generally static, the obtainment of valid quantitative data describing the faunal communities at the bottom of streams and ponds is feasible if adequate care is taken during the sampling and analytical procedures.

Probably the main disadvantage in dealing with these animals resides in the difficulty of providing taxonomic identifications to the requisite systematic levels unless the researcher is highly familiar with their characteristics. Even so, the complete identification of many groups to the lowest level possible requires the efforts of a taxonomic expert who has become specialized in working with a particular type of organism. Therefore, a great deal of effort has to be expended in order to obtain a high degree of taxonomic resolution. If this resolution is poor, the diversity measurements become less fine-tuned, and this tends to cloud the assessment phase of an inventory. As a further disadvantage, a considerable amount of sampling and analytical time is required to adequately and quantatively collect, sort, identify, and count a collection of these organisms. However, sufficient time was available in this project to largely circumvent such problems, and the Fort Union inventory produced a suitable level of taxonomic resolution for interpretive purposes that is in accord with the resolution that is typically obtained from most studies of this kind.

PROJECT HISTORY AND DURATION

The concept for initiating a two-year hydrobiologcal-benthic inventory in southeastern Montana's coalfield area first came to light in the summer of 1976. Feelers for funding opportunities were forwarded during that year, and the first research proposal was prepared in the spring of 1977. Notification of funding was received during the first few months of 1978, and the project was then christened with a preliminary field survey of the

study region in order to identify the appropriate sampling stations. Actual field work was started in May of 1978, and it was continued into November to complete the first year's sampling effort. A winter trip was also undertaken to a few of the more accessible stream locations. The project was ultimately extended for a second year so that field work was again conducted through a March to December period in 1979. Some of the sample analyses were completed in concert with the field sampling, but a major part of the laboratory effort that was required for the macroinvertebrate collections was expended after the termination of field activites. These analyses were largely completed by June, 1980, leading to the writing of the final reports.

SAMPLING STATIONS

Station Classes and Number

As indicated in Figure 1, 34 rivers and creeks of varying sizes and two lentic waters were sampled during the course of the project in the five minor drainage basins of the study region. This involved 43 separate and fairly well-defined sampling stations. Most of the rivers and creeks had only one collection site, often near its mouth, although five of the streams were collected at two separate spots while one of the creeks was sampled at three distinct locations. Table 1 presents a listing of the stations utilized in the inventory, and this table also references the site numbers contained in Figure 1 to a particular station name. The abbreviations or symbols that will be utilized for each of the streams and stations through the remainder of the report are also presented within this same table.

Three classes or types of stream sampling sites were identified for the coalfield aquatic inventory and collected for a particular set of parameters. These were termed the "intensive," the "accessory," and the "miscellaneous" stations of the study, and the three categories are noted in Table 1 by station. The main objective of sampling at the intensive sites was to provide for in-depth, replicated, and seasonal data for a select set of stream locations, and the objective of collecting at the accessory sites was to provide for a broad overview of the biological characteristics of a wide variety of waters in the southern Fort Union region. The intensive stations, therefore, were sampled much more frequently and for a wider spectrum of biological features than the accessory sites. However, a much greater assortment of accessory than intensive sites was collected during the project, and another point of working at the accessory locations was to afford a wide range of stream salinity concentrations that could be used for interpretive applications. Following the completion of the intentory, nine intensive and 24 accessory stations had been sampled, and all of these sites had been collected for the macroinvertebrate organisms.

In contrast to the intensive and accessory stations, the ten miscellaneous sites were sampled only on a few occasions and for an incomplete set of biological data relative to what was collected from the normal accessory locations. Such miscellaneous stations are denoted in Table 1 and represent the "curiosity" collections that were added to the main sampling program after the inventory got underway. In the main and with

Table 1. List of intensive (I), accessory (A), and miscellaneous (M) sampling stations established on streams in the southern Fort Union study region along with their accessibility and stream-type characteristics (the first page of two pages).

Station Number	Station Name	Station Symbol	Station Class	Station Accessibility	Stream Type*
07	Upper Rosebud Creek near Kirby	URsb-K	I#	Good	mlp
38	Unnamed Pond near Kirby	Pond-K	M	Good	sw
35	Middle Rosebud Creek near Colstrip	MRsb-C	A#	Poor	lp
36	Lower Rosebud Creek near Rosebud	LRsb-R	A#	Fair	lp
24	Indian Creek near Kirby	Indian	A#	Good	mlp
21	Davis Creek near Busby	Davis	A#	Good	si
29	Muddy Creek near Busby-Lame Deer	Muddy	A#	Good	sp
26	Lame Deer Creek near Lame Deer	Lame Dr	A#	Good	sp
18	Cow Creek near Colstrip	Cow-C	M	Poor	si
41	Tongue River near Sheridan-Decker	TR-ShD	A#	Good	mjp
25	Interstate Ditch near Sheridan-Decker	IDitch	M	Good	a
12	Ash Creek near Sheridan-Decker	Ash	A#	Good	sp
43	Youngs Creek near Sheridan-Decker	Youngs	A#	Good	sp
09	Tongue River near Pyramid Butte-Birney	TR-PBB	I#	Excellent	mjp
08	Squirrel Creek near Decker	Sqrrl	I#	Good	sp
22	Deer Creek near Decker	Deer	A#	Good	si
16	Canyon Creek near Decker-Birney	Canyon	A#	Excellent	sp
31	Prairie Dog Creek near Pyramid Butte-Birney	PrDog	A#	Fair	si-wg
15	Bull Creek near Pyramid Butte-Birney	Bull	A#	Poor	sp
20	Crazy Head Springs near Ashland-Lame Deer	CHS	M	Fair	sw
17	Cook Creek near Birney-Birney Village	Cook	A#	Fair	si-wg

*mlp--moderately large perennial based on flow; sw--standing water; lp--large perennial; si--small intermittent based on drainage area; sp--small perennial; mjp--major perennial; a--irrigation canal; wg--water-gap.

#Macroinvertebrates were collected from these stream sampling sites.

Table 1. Continued (the second page of two pages).

Station Number	Station Name	Station Symbol	Station Class	Station Accessibility	Stream Type*
28	Logging Creek near Ashland	Logging	A#	Good	si
14	Beaver Creek near Ashland-Brandenberg	Beaver	A#	Poor	sp?
03	Upper Hanging Woman Creek near Quietus-Decker	UHWC-D	I#	Good	sp
02	Lower Hanging Woman Creek near Birney	LHWC-B	I#	Excellent	sp
39	Stroud Creek near Quietus-Decker	Stroud	M	Good	si
27	Lee Creek near Quietus-Birney	Lee	M	Good	si-wg
01	East Fork of Hanging Woman Creek near Birney	EFHWC	I#	Excellent	sp-wg
13	Bear Creek near Otter	Bear	A#	Good	sp
30	Upper Otter Creek near Otter-Fort Howe	UOtr-O	A#	Good	sp
19	Cow Creek near Otter-Fort Howe	Cow-O	A#	Fair	sp
05	Lower Otter Creek near Ashland	LOtr-A	I#	Good	sp
06	Pumpkin Creek near Miles City	Pmpkn	I#	Very Poor	li
04	Mizpah Creek near Mizpah	Mizpah	I#	Very Poor	li
23	East Fork of Armells Creek near Colstrip	EFArm	M	Poor	si
42	West Fork of Armells Creek near Colstrip	WFArm	A#	Poor	si
10	Main Armells Creek near Colstrip	MArm-C	M	Poor	si
11	Lower Armells Creek near Forsyth	LArm-F	A#	Fair	sp
40	Sweeney Creek near Rosebud	Sweeny	A#	Fair	sp
34	Reservation Creek near Forsyth-Hysham	Reserv	A#	Fair	sp
37	Sarpy Creek near Hysham	Sarpy	A#	Fair	sp
33	Powder River near Moorhead	PR-Mo	M#	Very Poor	mjp
32	Powder River near Mizpah	PR-Mz	M#	Very Poor	mjp

*sp--small intermittent based on drainage area; sp--small perennial based on flow; ?--intermittent near mouth; wg--water-gap; li--large intermittent; mjp--major perennial.

#Macroinvertebrates were collected from these stream sampling sites.

two exceptions, macroinvertebrate information was not taken from the miscellaneous sites in favor of algal sampling, and as a result, macroinvertebrate data are on hand for only 35 of 43 project stations. These macroinvertebrate stations are identified in Table 1. Nevertheless, the data from the miscellaneous sites, though incomplete, should also make a contribution to any complete biological descriptions of the study area waters.

The Pumpkin and Mizpah Creek stations were classified as intensive sites for the first field season but sampled as accessory stations during the second year while the reverse was true for the Squirrel and East Fork Hanging Woman Creek locations. This mid-project change was initiated because of the intermittent nature and poor access of the Pumpkin and Mizpah Creek sites in contrast to the perenniality and more direct access of the other two streams in relation to the central core of the study area (Figure 1). It was felt that an adequate data base at the intensive level had been obtained for Pumpkin and Mizpah Creeks during the first year to satisfy the needs of the study. Furthermore, both Squirrel Creek and the East Fork of Hanging Woman Creek appeared to have a greater potential for being affected by coal development in the immediate future than the two more northern streams, and extra biological data from these two perennial waters seemed to better coincide with the main theme of the inventory.

Selection Criteria

Appropriate stream sampling sites were identified during the preliminary field survey of the study area, and such choices were made on the basis of several preconceived selection criteria. The most obvious of these was the requirement for an easy access to a station with its availability along the major travel routes. This criteria was felt to be especially important, particularly for the intensive sites, because of extensive size of the study area, the number of stations, and the number of samples to be collected. Table 1 presents a general description of the relative accessibility of each of the many sampling sites in relation to the location of the field facilities near Birney, Montana. The negative nature of this criteria with respect to certain of the stations accounts for the lower frequency of sampling at some of these streams.

The smaller streams of the study area were stressed in this inventory because very little in the way of biological data are on hand for this type of water in the Fort Union region. Many of these creeks are either perennial in nature, having shown a distinct flow on each of the project trips (e.g., Otter and Hanging Woman Creeks), or they have rather extensive drainage systems (e.g., Pumpkin and Mizpah Creeks), and these features formed another criteria for choosing many of the selected sites. To a large degree, therefore, attention was directed to the smaller perennial waters of the study area, although a handful of the intermittent and "water-gap" creeks and a few of the larger streams were also collected to insure a wider range of salinity levels. The term "water-gap" in this report refers to those streams that are continuously flowing or intermittent but only through generally short sections of their total length; that is, ephemeral reaches can be found between the flowing segments.

In contrast to the smaller streams, some biological information is available for the larger lotic systems of the region because of the

completion of earlier studies, e.g., Rosebud Creek (Baril, et al, 1978) and the Tongue River (Newell, 1977). However, these larger waters were still sampled as a component of this more recent investigation in order to provide a direct basis of data comparison between the benthic biology of the smaller aquatic systems and that in the first order streams. For this reason, intensive stations were located on Rosebud Creek and the Tongue River, but seven of the intensive sites were placed on the more important smaller creeks of the area. In the case of the accessory stations, a wide variety of the small and large streams were collected as a means of gaining the broad biological overview that was required from this phase of the inventory. In addition, two ponds were sampled as miscellaneous stations. Table 1 categorizes the waters that were sampled during the study on the basis of their flow characteristics. These "stream-type" descriptions are based only upon the field observations that were made during the many trips through the project area and not on any extra-study information.

Another of the selection criteria involved the placement, as feasible, of a project sampling station in close vicinity of a USGS water quality and flow monitoring site so that the data produced by the USGS programs might be used in relation to the biological data collected as a part of this study. Such USGS sampling efforts in the Fort Union region are summarized in one of their open-file reports (USGS, 1979a), and the applicable USGS stations are listed in this study's data report (Klarich, et al, 1980). This criteria was applied to the station selection process whenever it proved to be amendable to the other requirements of the inventory.

Station Locations and Definition

Table 1 provides a listing of the project area sampling stations, and Table 2, in turn, presents the geographic descriptions for these sites using the township (T)-range (R)-section (last two-digit number)-subsection (letter) system utilized by BLM. An attempt was made throughout the study to sample a different specific stream location on each visit to a station in order to prevent a biasing of the more recent macroinvertebrate collections. To accommodate this sampling need, each of the stations was defined as containing a considerable length of water both above and below the direct access point, and the application of this definition provided the opportunity to avoid a resampling of the same stream bottom materials. In many cases, these different site locations were close enough together to have the same geographic description at the quarter section level, but in some instances, these locations were so oriented, or were far enough apart, to require different designations.

The first description of each site in Table 2 denotes a general length of stream that was sampled most frequently at a station. The second designation, if present, refers to an important alternate location of the station, requiring a separate designation, that was collected on a fair percentage of the site visitations (at least twice at a minimum). The descriptions presented in Table 2 account for about 91% of the samples taken from the study area. The other locations that correspond to the remainder of the collections are summarized in the appendix of the project data report, and this same summary directly relates each of the many inventory samples and their collection dates to a particular geographic designation.

Table 2. Geographic descriptions of the study area sampling station locations and other related items (the first page of two pages).

Station Number	Station Symbol	Main Sampling Location(s)	Basin Code*	Drainage Basin	Tributary To:
07	URsb-K	T06S,R39E,20C	42A	Upper Rosebud	Yellowstone River
38	Pond-K	T05S,R38E,36A	42A	Upper Rosebud	(Rosebud Creek)
35	MRsb-C	T01N,R43E,19A	42A	Middle Rosebud	Yellowstone River
36	LRsb-R	T06N,R42E,16D	42A	Lower Rosebud	Yellowstone River
24	Indian	T06S,R39E,31D	42A	Upper Rosebud	Rosebud Creek
	"	T06S,R39E,31C			
21	Davis	T04S,R38E,11D	42A	Upper Rosebud	Rosebud Creek
29	Muddy	T02S,R40E,35C	42A	Middle Rosebud	Rosebud Creek
26	Lame Dr	T03S,R41E,10A	42A	Middle Rosebud	Rosebud Creek
	"	R03S,R41E,03B			
18	Cow-C	T01N,R43E,06D	42A	Middle Rosebud	Rosebud Creek
41	TR-ShD	T57N,R84W,01CA#	42B	Upper Tongue	Yellowstone River
	"	T57N,R84W,01CB#			
25	IDitch	T57N,R84W,01B #	42B	Upper Tongue	(Tongue River)
12	Ash	T57N,R84W,01B #	42B	Upper Tongue	Tongue River
43	Youngs	T58N,R83W,30B #	42B	Upper Tongue	Tongue River
09	TR-PBB	T06S,R42E,31D	42B	Upper Tongue	Yellowstone River
08	Sqrrl	T09S,R40E,29CD	42B	Upper Tongue	Tongue River
	"	T09S,R40E,29CB			
22	Deer	T09S,R41E,10C	42B	Upper Tongue	Tongue River Reservoir
16	Canyon	T07S,R41E,11C	42B	Upper Tongue	Tongue River
31	PrDog	T06S,R42E,31D	42B	Upper Tongue	Tongue River
	"	T06S,R41E,26A			
15	Bull	T06S,R42E,19A	42B	Upper Tongue	Tongue River
20	CHS	T02S,R42E,35C	42B	Upper Tongue	(Logging Creek)
17	Cook	T05S,R42E,25B	42C	Middle Tongue	Tongue River
28	Loggng	T03S,R44E,20C	42C	Middle Tongue	Tongue River
	"	T03S,R44E,28A			
14	Beaver	T01S,R46E,20B	42C	Middle Tongue	Tongue River
	"	T01S,R45E,10D			

*Codes were obtained from a USGS (1968) basin map. #Wyoming designations.

Table 2. Continued (the second page of two pages).

Station Number	Station Symbol	Main Sampling Location(s)	Basin Code*	Drainage Basin	Tributary To:
03	UHWC-D	T08S,R43E,16C	42B	Upper Tongue	Tongue River
	"	T08S,R43E,17D			
02	LHWC-B	T06S,R43E,19D	42B	Upper Tongue	Tongue River
	"	T06S,R43E,18D			
39	Stroud	T08S,R43E,02A	42B	Upper Tongue	Hanging Woman Creek
27	Lee	T07S,R44E,20D	42B	Upper Tongue	Hanging Woman Creek
01	EFHWC	T06S,R43E,20DB	42B	Upper Tongue	Hanging Woman Creek
	"	T06S,R43E,20DA			
13	Bear	T07S,R45E,27A	42C	Middle Tongue	Otter Creek
30	UOtr-O	T07S,R45E,13D	42C	Middle Tongue	Tongue River
	"	T07S,R46E,06B			
19	Cow-O	T06S,R45E,17D	42C	Middle Tongue	Otter Creek
05	LOtr-A	T03S,R44E,12C	42C	Middle Tongue	Tongue River
06	Pmpkn	T06N,R48E,35C	42C	Lower Tongue	Tongue River
04	Mizpah	T06N,R51E,24C	42J	Lower Powder	Powder River
	"	T06N,R51E,25C			
23	EFArm	T03N,R41E,28C	42KJ	Middle Yellowstone	Armells Creek
42	WFArm	T04N,R40E,32B	42KJ	Middle Yellowstone	Armells Creek
10	MArm-C	T04N,R40E,16B	42KJ	Middle Yellowstone	Yellowstone River
11	LArm-F	T06N,R39E,26B	42KJ	Middle Yellowstone	Yellowstone River
	"	T06N,R39E,23D			
40	Sweeny	T06N,R43E,22A	42KJ	Middle Yellowstone	Yellowstone River
34	Reserv	T06N,R38E,26B	42KJ	Middle Yellowstone	Yellowstone River
	"	T06N,R38E,23A			
37	Sarpy	T06N,R37E,20A	42KJ	Middle Yellowstone	Yellowstone River
	"	T06N,R37E,07C			
33	PR-Mo	T09S,R48E,08C	42J	Upper Powder	Yellowstone River
32	PR-Mz	T06N,R42E,30D	42J	Lower Powder	Yellowstone River

*Codes were obtained from a USGS (1968) basin map.

COLLECTION CHARACTERISTICS AND SAMPLING FREQUENCY

A large proportion of the inventory's macroinvertebrate samples were collected from natural stream substrates using standard Surber sampler methodologies. This technique was applied to all of the intensive and accessory stations, although only a few collections of this kind were taken from the miscellaneous sites. As a further sampling manipulation, artificial substrates (jumbo multiplate, Hester-Dendy samplers) were also used at the intensive sites as means of obtaining additional macroinvertebrate samples; however, this application was not made at the accessory and miscellaneous locations for logistic reasons. The data obtained from the artificial substrates provide a somewhat different interpretive base for the study relative to what would have been available from the natural substrates alone, and because of this feature, a generally wider biological perspective is on hand for the intensive stations relative to that for the accessory sites. This restriction of artificial substrate work to the intensive stream locations represents one of the most significant differences between the intensive and accessory sampling stations of the project.

Another of the main differences between the intensive and accessory classes of inventory stations resides in the frequency of collection where Surber sampling was much more intense at the first type of site. An attempt was made to collect such intensive locations using this technique on a monthly basis through a mid-spring to mid-fall period during each of the two field seasons so that at least one set of data might be available for each of the months within this time frame. As a result, six to eight natural substrate samples were obtained from each of the intensive sites during each year of the project. In contrast, only one to three Surber collections were typically obtained from the accessory stations during any of the two field seasons. This then totals between one and seven collections of this kind for each accessory location through the entire study in comparison to the 14 to 19 samples typically obtained from an intensive site. The completion of Surber sampling during different months was also planned for the accessory sites in order to obtain some level of seasonal data for these stream locations also. But this requirement could not always be completely fulfilled because of scheduling conflicts with the many field trips to the intensive stations.

With the level of sampling activity described above, both intra-year and inter-year duplicate monthly data were obtained for some of the months at most of the collection sites. Furthermore, additional macroinvertebrate samples were obtained for a few of the months via the artificial substrate applications that were made at the intensive stations. This artificial substrate work first involved three stream habitats at each of the intensive locations, and it also involved two exposure periods and two collection dates during each of the two field seasons. The details of this phase of the project will be described in the next chapter of this report.

Table 3 lists the quantity and types of macroinvertebrate samples that were collected from the many stream locations during the two years of this project. As indicated in the table, a large number of water samples for salinity evaluations were also obtained from the study area streams in conjunction with the biological collections. Table 3 also points to a great deal of variation among the stations in relation to the

Table 3. Numbers and types of macroinvertebrate samples and numbers of salinity measurements taken from the study area streams.

Station Number	Station Symbol	Station Class	Sal	Natural Fi	Se	To	UA	Artificial Fi	Se	To	NC
07	URsb-K	I	21	8	6	14	0	6	6	12	0
38	Pond-K	M	0	0	0	0	0	0	0	0	0
35	MRsb-C	A	6	2	1	3	0	0	0	0	0
36	LRsb-R	A	5	0	1	1	0	0	0	0	0
24	Indian	A	9	3	3	6	0	0	0	0	0
21	Davis	A	4	2	1	3	0	0	0	0	0
29	Muddy	A	6	2	2	4	0	0	0	0	0
26	LameDr	A	6	2	2	4	0	0	0	0	0
18	Cow-C	M	1	0	0	0	0	0	0	0	0
41	TR-ShD	A	8	2	2	4	0	0	0	0	0
25	IDitch	M	1	0	0	0	0	0	0	0	0
12	Ash	A	5	1	2	3	0	0	0	0	0
43	Youngs	A	6	0	2	2	0	0	0	0	0
09	TR-PBB	I	21	7	6	13	0	3	5	8	4
08	Sqrrl	I	15	2	7	9	0	0	6	6	0
22	Deer	A	5	2	1	3	0	0	0	0	0
16	Canyon	A	6	0	3	3	0	0	0	0	0
31	PrDog	A	5	0	2	2	0	0	0	0	0
15	Bull	A	3	0	2	2	0	0	0	0	0
20	CHS	M	1	0	0	0	0	0	0	0	0
17	Cook	A	4	2	1	3	0	0	0	0	0
28	Loggng	A	5	2	1	3	0	0	0	0	0
14	Beaver	A	6	3	2	5	0	0	0	0	0
03	UHWC-D	I	22	8	6	14	0	5	6	11	1
02	LHWC-B	I	25	7	9	16	2	6	6	12	0
39	Stroud	M	3	0	0	0	0	0	0	0	0
27	Lee	M	1	0	0	0	0	0	0	0	0
01	EFHWC	I	19	4	7	11	0	0	6	6	0
13	Bear	A	4	0	3	3	0	0	0	0	0
30	UOtr-O	A	8	2	5	7	0	0	0	0	0
19	Cow-O	A	3	0	2	2	0	0	0	0	0
05	LOtr-A	I	22	7	8	15	1	5	6	11	1
06	Pmpkn	I	11	6	2	8	0	4	0	4	2
04	Mizpah	I	10	6	2	8	0	5	0	5	1
23	EFArm	M	3	0	0	0	0	0	0	0	0
42	WFArm	A	4	1	1	2	0	0	0	0	0
10	MArm-C	M	2	0	0	0	0	0	0	0	0
11	LArm-F	A	6	0	3	3	0	0	0	0	0
40	Sweeny	A	7	2	2	4	0	0	0	0	0
34	Reserv	A	7	3	2	5	0	0	0	0	0
37	Sarpy	A	7	2	2	4	0	0	0	0	0
33	PR-Mo	M	1	0	1	1	0	0	0	0	0
32	PR-Mz	M	1	0	1	1	0	0	0	0	0
	Totals		315	88	103	191	3	34	41	75	9

Station classes: I--intensive, A--accessory, and M--miscellaneous. Sal--salinity samples. Natural--natural substrate Surber samples: Fi--first year, Se--second year, To--total, and UA--unanalyzed collections. Artificial--artificial substrate samples: NC--substrates not collected because of damage, loss, or some other factor.

numbers of salinity and macroinvertebrate samples that were taken from the streams, and a major part of this variation is due to the differences in sampling frequency between the intensive and accessory classes of stations. Another contributing factor to this difference in sample numbers was the mid-project change in the intensive-accessory status of Pumpkin, Mizpah, Squirrel, and East Fork Hanging Woman creeks so that fewer collections were ultimately obtained from these four streams than from the other intensive waters. In addition, some of the accessory sites were only sampled during the second field season and not during the initial year, resulting in a lower number of samples, and the general inaccessibility of some of the sampling locations also reduced the opportunities to visit these particular streams to some extent. As a final factor, the miscellaneous stations were not typically collected for the macroinvertebrate organisms. Regardless, 266 macroinvertebrate samples were obtained from the study area streams and analyzed during the two-year span of the inventory.

RELATED WORK

Along with the salinity evaluations, the main core of data generated by the inventory describes the kinds of macroinvertebrate and algal-periphytic taxa encountered in the study area streams, details the abundances of these taxa, and establishes the diversities of the benthic macroinvertebrate and periphytic associations. Bahls (1980) has considered the algal aspects while this publication deals with the faunal components. However, other types of information were also collected during the project that have not been reviewed in these two interpretive reports. This restriction was initiated in order to delimit the contents of the reports to the central theme of the inventory as outlined in the two research proposals.

Some of the extra project information has been summarized in the companion data report (Klarich, et al, 1980) as follows: water quality analyses in addition to salinity, macroinvertebrate biomass, physical measurements (stream width, depth, flow, and current velocity), and substrate delineations. Extra data that have not yet been tabulated in any of the first three reports are periphyton production, algal biomass, autotrophic indices, and aquatic macrophyte taxa, distribution, and relative abundance. In addition, the results from terrestial insect collections, aquatic and non-benthic macroinvertebrate collections, benthic pool samples, and some fishery work have not been closely examined. Eventual considerations along these lines will help to further characterize the biological characteristics of the coalfield area streams, and it is hoped that additional funding will be granted so that future attention can be focused upon these related topics.

METHODS

SALINITY EVALUATIONS

Water samples that were used in the salinity analyses were obtained from the study area streams in liter plastic bottles in close association with almost all of the biological collections. Specific conductance (SC) was utilized as a measure of salinity using a model MC-1, Mark IV, Lab-Line

Lectro Mho-Meter that had been calibrated with a 0.01 M KCl solution equivalent to 1413 micromhos per cm. Temperature corrections to the 25 C standard were made on the instrument. SC data for the southern Fort Union streams are also available from the USGS for the period of study in either a published form (USGS, 1979b) or as provisional data that will be published in the near future (USGS, 1980 and 1981). USGS water quality information that was collected before October 1, 1978, has been published while that collected after this date still has a provisional status at the time of this writing.

Since many of the benthic macroinvertebrates are relatively long-lived, the salinity aspect of the inventory was related to the biological data as an average of all the SC values that were on hand for a stream station through a one-month period immediately prior to the collection date of a benthic sample. The SC reading that was obtained on the day of sampling was also used in computing this statistic. Such means should afford a better representation than the single collection day value of the overall levels of salinity affecting the stream organisms in relation to their entire life spans, and an increasingly valid representation of the salinity factor is gained as more daily SC numbers become available.

In the case of many of the project area waters, however, the single SC reading that was measured on the day of sampling was not exceedingly different from a SC mean since this parameter did not generally demonstrate a great deal of day-to-day variability within the streams during the low flow periods. As a result, the number of SC readings that were secured for a one-month period did not turn out to be an overly important feature with reference to this particular application. This proved to be a fortunate circumstance because a single collection day value was often the only one-month reading available for many of the less frequently sampled stream locations. But such SC means were calculated for each of the macroinvertebrate samples to the best extent possible using the appropriate inventory data plus all of the applicable published and provisional data received from USGS for the corresponding stations.

MACROINVERTEBRATE FIELD SAMPLING

Natural Substrates

Type of Sampler and Applications. A Surber stream-bottom sampler following the design pictured in Slack, et al (1973) was utilized to collect 72% of the inventory's benthic macroinvertebrate samples. This piece of equipment consists of a horizontal metal frame that delineates a square-foot sampling area along with a vertical frame that supports the collection net. The nylon net used in this project had a mesh size generally equivalent to that of a Standard Number 30 sieve (Weber, 1973). The successful application of the Surber technique requires the presence of a fairly distinct current to sweep the aquatic organisms into the net, and because of this requirement, the riffles and channels of the study area streams, by having the required current velocities, were stressed in the Surber phase of the project over the more ponded stream segments. As a result, a somewhat consistent type of stream habitat was examined among most of the collection stations throughout a major portion of the sampling program. However, an ideal sampling reach of this kind could not be found at a few of the project sites, and in these cases a less than ideal spot had to be

used with no other options available.

After the selection of an appropriate sampling location and the placement of the Surber into the stream, the top six to nine inches of bottom materials bounded by the square-foot sampling perimeter were excavated after gentle agitation and placed into the net portion of the sampler. Any of the benthic macroinvertebrates that happened to be dislodged from the substrates by this initial collection effort were then captured by the Surber set. The Surber apparatus with its contained substrates and netted organisms was subsequently moved to the shore where the substrates were placed into a Number 30, circular metal sieve positioned over a board base for the removal of the remaining animals. Macroinvertebrates collected from the stream materials were gradually transferred to a labelled sample container through the entire on-site picking process for eventual preservation, and the net, sieve, and board were also checked and cleaned. The smaller types of substrates that could not be easily surveyed in the field, such as the detritus, macroalgae, and finer rock particles, were also added to the same container for later picking under laboratory conditions. The larger stream bottom materials were discarded after the attached macroinvertebrates had been removed. Knives, wash-bottle spray, brushes, and tweezers were used to dislodge and pick the organisms from the different kinds of substrates.

In those cases where a large rock or some other form of large substrate was found to be only partially contained within the square foot sampling area, a knife was used to scrape a line on the substrate to mark the sampling boundary. The portion of the substrate that was located outside of the perimeter was then cleaned instream so that the organisms would be washed away from the collection net. These substrates were then moved to the shore to be picked along with the other materials. Such sampling obstructions were encountered on occasion since specific stream sampling spots were chosen as randomly as possible throughout the study once an adequate stream section for the Surber work had been selected on a particular visit to the station.

Immediately following the field cleaning of a collection, the macroinvertebrates and other materials contained in the sample bottle were preserved with ethanol for transport and for storage until further analytical work could be directed to the sample. A small amount of rose bengal dye was added to the alcohol before its use in order to impart a pinkish color to the organisms so that they would be easier to recognize in midst of the sample debris during the final picking activities eventually undertaken in the laboratory.

Through the application of this sampling approach, a large percentage of the benthic macroinvertebrates that had occupied the square-foot by six to nine inch deep layer of stream substrate were actually collected as a discrete quantitative sample that could be used for further evaluations. Some of the smaller benthic organisms that might be best classified as microinvertebrates were also collected since the net and sieve were not employed as actual straining devices. But of the possible microinvertebrates, only the very young and thereby relatively small representatives of the commonly larger forms were considered in the final analysis.

Replications. In terms of field sampling replications at the many stream locations, the following two general guidelines were used for the Surber collections: (1) For the relatively rich sites showing a larger number or high density of organisms, only one sample was typically collected on each of the site visitations; but for the less rich sites showing a comparatively small number or low density of benthic macroinvertebrates, duplicate or triplicate samples were often taken and composited into a single container. (2) For the stream locations having large quantities of benthic macroalgae, only one sample was generally obtained because of the excessive time requirement associated with completely cleaning and picking such collections. In the case of many of the creeks, the application of one Surber actually covered a large proportion of the stream width, and single samples from these streams would appear to be fairly representative of the actual benthic populations. In turn, single samples from the smaller streams are probably more valid than those obtained from the larger waters. However, duplicate and triplicate collections were made on occasion from all types of streams in the study area, and on some of the station visits, the subsamples were added to different containers to afford the option for a separate laboratory analysis and the option for a comparison of the two sets of data. But for the final tabulations, any macroinvertebrate data in the form of two or three subsamples for a station and date were appropriately combined in all instances.

Artificial Substrates

Type of Sampler and Applications. The use of artificial substrates at the nine intensive stations provided some flexibility to the sampling program since this methodology is not restricted by the lack of a stream current as is the case for the Surber technique. With the application of these substrates, therefore, some attention could also be directed to the macroinvertebrates that are found in the pools of the streams as well as their flowing segments. This attribute eventually became the main reason for employing artificial substrates in the project, although the data obtained from this sampling approach also acts to supplement the information that was collected via the Surber sampler from the natural stream bottom materials in the riffle and channel reaches. About 28% of the project's macroinvertebrate samples were obtained by using artificial substrates.

The jumbo multiplate type of Hester-Dendy sampler was utilized as the artificial substrate in this inventory, and this apparatus is generally similar, with some minor modifications, to the illustration that is presented in Slack, et al (1973). The jumbo multiplate variety consists of a stack of thirteen, three inch by three inch masonite plates, 1/8 inch in depth, that are separated by varying distances from each other through the placement of a differing number of one inch by one inch, 1/8 inch deep spacers of the same material in between the main squares. The whole assembly is held together by an eight inch eyebolt placed through the center of the stack. If the eye of the bolt is visualized as the top of the sampler, the thirteen main plates are differently spaced from the top to the bottom as follows: 1/8 inch (one spacer) between the first eight squares, 1/4 inch (two spacers) between the last plate of the first set and the following plate, and 3/8 inch (three spacers) between the last five squares. The larger number of plates and their variable spacing represents the major difference between the kind of Hester-Dendy sampler described by Slack and

the jumbo multiplate device that was used in this study.

The overall design of the Hester-Dendy sampler provides for the availability of variably sized "hidey-holes" that tend to simulate the character of the natural stream bottom substrates to some extent. With the positioning of the sampler on the stream bottom, this feature induces an immigration to and colonization of the sampler by the stream's benthic organisms. After a suitable enticement or exposure period, the colonizers can then be collected from the stream with the careful removal of the sampler from the water. The results from this sampling approach are semi-quantitative in nature, although the data became more quantitative and reproducible for a prescribed set of conditions as the exposure period approaches some ideal length. However, because of the basic differences in application, the Surber collections and the Hester-Dendy collections should not be expected to be closely comparable even when obtained on the same date and from the same stream habitat and station.

Sets of duplicate jumbo multiplate samplers were placed into three stream locations at each of the intensive sites, and they were held in place by wires attached from the eyebolts of the samplers to instream or onshore anchors. The three locations at a sampling site were chosen to reflect three different types of lotic benthic habitats at a fairly general level as follows: (1) a relatively shallow riffle section having a rapid current that was also used to conduct some of the Surber work; (2) a much deeper and ponded segment of the stream having a very slow current; and (3) a transitional or riffle to pool type of reach having intermediate depth and velocity characteristics relative to the other two segments. The morphometry of most of the study area streams delineate a sequence of fairly extensive ponded reaches connected by short riffle segments, and because of this feature, all of the samplers of a station triumvirate, regardless of their different habitat requirements, could be situated in close vicinity of one another at all of the sites.

<u>Exposure Periods and Retrieval</u>. Two exposure periods and two subsequent collections of the artificial substrates from the three stream habitats were planned for the intensive sites during each of the two field seasons. This sampling program would provide a maximum of twelve macroinvertebrate samples of this kind from each of the intensive stations for the entire project, and four samples would then be obtained from each of the stream locations. But because of the change in site classifications, artificial substrate sampling was conducted for only one field season at the Pumpkin, Mizpah, Squirrel, and East Fork Hanging Woman Creek stations, and this switch resulted in the obtainment of a lower number of Hester-Dendy samples from these streams than from the others with only two collections from each habitat. Furthermore, an <u>in situ</u> 10% loss of the samplers was incurred during the study as a result of washouts, beachings, cattle trampling, and so on, and these losses also reduced the number of artificial substrate samples that could be procured from some of the sites.

The artificial substrates were first introduced to the streams during an early to midsummer period of each year, and the samplers were initially collected and reintroduced after cleaning for a second exposure during the late summer or early fall. The samplers were then collected for a second time and removed from the field to terminate a sampling cycle during the

mid-fall season of the same year. Exposure periods of 1.5 months before collection were planned for all of the samplers, but this requirement was not always possible to meet because of field scheduling conflicts and because of the need to reintroduce certain of the samplers that had been found in a disturbed condition. As a result, the individual exposure periods varied somewhat around the 1.5 month value, and 86% of the samplers were exposed to the streams for greater than one month, 47% were exposed for more than 1.5 months, and 8% were exposed for more than two months. These exposure periods ranged from 18 days in a very few cases to 63 days in a few other instances, and they averaged about 1.5 months (42 days) for all of the samplers through the entire study.

Following an exposure period, the collection of the duplicate samplers from a stream habitats involved the underwater use of a Number 30 mesh sieve that was placed under the samplers before their withdrawal through the water column. The artificial substrates could then be carried on the sieve which acted as a catch basin to prevent a loss of the organisms that might have been washed out of the samplers during their removal from the streams. This same metal sieve was used in all of the project manipulations, and it had a one foot diameter and a three inch depth. The sieve and the samplers were eventually moved to the shore where the substrates were thoroughly picked, rinsed, sprayed, scraped, and jarred to dislodge the still attached macroinvertebrates. As a final step, the collected organisms were transferred from the sieve and the duplicate samplers to a single container where the composite sample was preserved with an ethanol-rose bengal solution as described for the Surber collections. The cleaned substrates were then either replaced in the streams or removed from the field depending upon the time of the year, and the preserved and labelled samples were transported to the laboratory and stored until further assessments could be made on the organisms.

MACROINVERTEBRATE LABORATORY ANALYSES

Sample Cleaning, Sorting, and Taxa Enumerations

Both the natural substrate and the artificial substrate macroinvertebrate samples were analyzed in the laboratory following the same general procedures. The collection was first placed into the Number 30 sieve, and after a rinsing of the sample bottle over the sieve, the initial step of the process involved the removal of any still attached organisms from the larger substrate materials such as rocks and twigs. The macroinvertebrates that were picked in this early step were transferred to a white metal-porcelain pan with the cleaned substrates returned to the original sample bottle. The rest of the sieve contents were washed to remove the finer sediment particles, and the "washate" was checked for the occurrence of any small but readily obvious organisms. After these preliminary steps, the remainder of the sample, which included the macroinvertebrates plus the associated rubbish, was dumped from the sieve into the same porcelain pan containing the previously collected organisms, and these contents were painstakingly mixed and randomized to an even coverage over the bottom of the container. This pan had the dimensions of 14.5 inches by 8.5 inches with a 2.5 inch depth, and the sample, at this stage of its preparation, was divided into four 7.25 by 4.25 inch parcels (quarters) for a final picking of the macroinvertebrates from the nonessential debris.

If the sample contained a low number of organisms, or if the sample was relatively clean with only small amounts of macroalgae and extraneous materials, then the entire sample (all four quarters) was picked. The condition of the collection in this regard became an important consideration because large quantities of macroalgae proved to be particularly bothersome to the final cleaning process. Therefore, if a large number of macroinvertebrates were present, and/or if the sample was found to be particularly "dirty," then only one or two diagonally opposite quarters (subsamples) were picked as feasible because of analytical time constraints. Environmental Protection Agency guidelines (Weber, 1973) for the laboratory subsampling of macroinvertebrate collections were followed in the study.

The next two steps of the analytical process can be described as follows: First, the large and obvious macroinvertebrates were removed from one to four of the subsample quarters as appropriate and placed into other containers. Second, small aliquots (tablespoons full) of the collection were sequentially taken from the porecelain pan and transferred to a ten centimeter diameter dish. After each transfer, the aliquot was flooded and surveyed with an A. O. Spencer, stero binocular dissecting scope with variable magnification so that all of the remaining organisms of a subsample might be spotted and removed. Throughout the application of these two steps, each of the picked macroinvertebrates was identified taxonomically and placed according to taxa into labelled (station, date, and taxa), friction-sealed petri dishes containing a small amount of alcohol preservative until the entire set of subsamples of a collection had been cleaned of all its organisms. The sample was thereby sorted taxonomically with each of the petri dishes associated with a particular field collection and with each of the dishes containing the individuals of a particular taxon.

Enumerations of the taxa individuals were ultimately taken from the petri dishes as a final analytical step, and the numbers were recorded by taxa on the dishes and on a station-collection date data sheet. In addition, the occurrence of duplicate or triplicate field sampling and the occurrence of laboratory subsampling was also noted on these same sheets. After the counts were completed, the dishes were stored in large, sealed containers for future reference and for an eventual biomass assessment of the collected organisms. Any of the unanalyzed subsamples that were left in the porcelain pan were returned to the original sample bottle, including the remaining debris, for storage and for other applications.

Taxonomic Identifications

The most difficult aspect of the laboratory analyses of the macroinvertebrate samples revolved around the taxonomic identifications of the many organisms collected during the project. Such identifications had to be carried to suitable systematic levels in order to provide for valid and meaningful diversity measurements. However, no plans were made to spend a great deal of time with the taxonomically difficult forms, and this basic precept, as developed in the initial research proposal (Klarich, 1977), was followed throughout the course of the laboratory work. In general, the macroinvertebrate identifications were carried to the lowest systematic level possible in relation to the objectives and theme of the study, in relation to the expertise of the project workers and their

associates, in relation to the information that was available to these individuals, and in relation to the time constraints that were imposed upon the inventory by the large number of samples. Although not ideal, an adequate taxonomic resolution was obtained from this work to afford acceptable diversity evaluations for the project.

To provide the necessary background for the taxonomic identifications, a study library was first compiled of applicable macroinvertebrate reference sources that could be used during the laboratory phase of the project. This library consisted of both general and specific references with the latter items providing the requisite keys and related information that were needed for identifying the taxa of a particular group of organisms. The general references, in turn, commonly covered a broad range of organisms and were used to confirm and check keying steps, to delineate taxa systematics, and to provide for descriptive and illustrative materials. A list of the general and specific macroinvertebrate references that were utilized in this inventory are presented in Table 4.

Through the use of this library, identifications to genera were possible for some of the groups while species recognitions were feasible in a few isolated and unique instances. With some exceptions, most of the Insecta, the Amphipoda (crustacean sideswimmers), the Hirudinea (leeches), the Gastropoda (snails), and the Pelecypoda (clams and mussels) could be keyed to these lower systematic levels. But even in many of these cases, generic identifications could not be made because of the small size of the specimens or because of their inadvertent mutilation during field collection and sample processing; both of these factors resulted in an obscuring of critical taxonomic features.

In contrast, some of the macroinvertebrate groups could only be identified to a higher systematic taxa above the generic level because of the general difficulty in keying these forms and/or because of the lack of suitable keys and keying characteristics. The Chironomidae insect family (midges), the Hydracarina group (aquatic mites), the Oligochaeta class (aquatic earthworms), the Turbellaria class (flatworms), the Nematoda class (aquatic roundworms), and the Goriida order (horsehair worms) provide the principal examples of these more ambiguous organisms. Further identifications of these particular animals would have demanded the efforts of expert taxonomists, or an excessive expenditure of project time, and both of these requirements were beyond the tenants of this current study. In all cases, only those taxonomic identifications that were felt to be fairly secure at a particular systematic level were accepted for the inventory, and the unreasonable "forcing" of the identifications to lower systematic categories in light of the available information was avoided throughout the study. Name verifications for many of the macroinvertebrates have been obtained from various non-project individuals who are also working in the same taxonomic field, and any identifications that were still felt to be somewhat tentative have been noted as such in the data tabulations.

Reference Collection

Through the entire process of sorting and identifying the organisms that were obtained with the many macroinvertebrate samples of the study, a few individuals of most of the different taxa were selected from among these

Table 4. List of taxonomic references used to identify the aquatic macroinvertebrate taxa collected during the inventory and delineate their systematic relationships.

Authors(Publication Year)--Title(Application = Number Code and Footnote)

Brown, H. P. (1972)--Aquatic Dryopoid Beetles (Coleoptera) of the United States (1)

Brunson and Lee (Undated)--"Key to Genera of Mollusks of Montana" (1)

Burch, J. B. (1972)--Freshwater Sphaeriacean Clams (Mollusca:Pelecypoda) of North America (1)

Edmondson, W. T. (1959)--Ward and Whipple's Fresh-Water Biology (4)

Edmunds, G. F., Jr., et al (1976)--The Mayflies of North and Central America (1)

Gaufin, A. R., et al (1972)--"The Stoneflies of Montana" (1)

Holsinger, J. R.(1972)--The Freshwater Amphipod Crustaceans (Gammaridae) of North America (1)

Johannsen, A. O. (1969)--Aquatic Diptera (1)

Klemm, D. J. (1972)--Freshwater Leeches (Annelida:Hirudinea) of North America (1)

Merritt, R. W. and K. W. Cummins (1978)--An Introduction to the Aquatic Insects of North America (3)

Pennak, R. W. (1978)--Freshwater Invertebrates of the United States (4)

Roemhild, G. (1975)--The Damselflies (Zygoptera) of Montana (1)

Roemhild, G. (1976)--Aquatic Heteroptera (True Bugs) of Montana (1)

Roemhild, G. (1976)--"Tentative Checklist of Montana Dragonflies" (1)

Stewart, P. (1974)--"Aquatic Invertebrates" (3)

Storer, T. I. and R. L. Usinger (1957)--General Zoology (3)

Usinger, R. L. (1956)--Aquatic Insects of California (2)

Wiggens, G. B. (1977)--Larvae of North American Caddisfly Genera (1)

(1) Specific references described by the title; (2) specific reference used for the coleopterans (beetles); (3) general references; (4) general references also used for the molluscs (snails and clams-mussels).

samples for a deployment into the project's macroinvertebrate reference collection. The initial taxonomic identifications of these specimens were made using the keys that are included in the inventory's reference materials as listed in Table 4. Although some of the more readily recognizable organisms have not been added to this collection, select individuals of all of the rarer taxa and select individuals of all of the taxonomically difficult forms have been chosen for this application. These particular representatives of a macroinvertebrate taxa were generally selected from the individuals available to provide the best illustration of their critical taxonomic features. The components of the reference collection are being stored with an alcohol preservative in labelled (taxa and sample information), airtight vials, and the collection is open to perusal by any interested parties. A listing of the different taxa contained in this collection is presented in the appendix of this report.

In addition to the reference library, the development of the macroinvertebrate reference collection afforded another avenue by which to gain the many taxonomic identifications that were required for the inventory. In this case, the reference specimens could be examined by other macroinvertebrate taxonomists that were called on to provide but mainly confirm the nomenclature and systematics of a particular kind of organism. With the availability of this collection, most of the macroinvertebrate taxa obtained from the study area streams have been verified in this fashion, and the collection will be on hand if the need for any future verifications or additional identifications should happen to arise. Furthermore, the collection was also heavily used by project workers throughout the laboratory phase of the project to double-check taxonomic identifications, to confirm keying features, and to compare various organisms. Through these applications, most if not all of the inventory organisms appear to have appropriate and correct taxonomic handles at the present time that are in accord with the general capabilities of the study.

DATA REDUCTIONS, REFINEMENTS, AND ASSESSMENTS

Preliminary Manipulations

The taxa counts included on the station-data data sheets for the Surber and Hester-Dendy samples represent the raw macroinvertebrate data of the project, and these numbers are not directly comparable in many instances because of the obtainment of extra samples on a particular site visitation and/or because of the advent of laboratory subsampling. Thus, the first step in assessing the project data demanded a refinement of these raw numbers to some comparative base. For the Surber collections, such adjustments involved a quantitative density estimate of each of the taxa for each of the sampling sites and sampling dates, i.e., the number of taxon individuals per square foot of stream bottom. Such density determinations required, for the composited samples, a correction for duplicate-triplicate field sampling through an appropriate division and/or a correction for laboratory subsampling through an appropriate multiplication step. For the non-composited and duplicate-triplicate Surber samples, a separate count analysis was first needed for the different sub-collections which was followed by a correction for laboratory subsampling as necessary, and the calculation of an average density value for each of the taxa then represented the final step of these data refinements.

For the artificial substrate collections, the refined data were calculated as the numbers of taxa individuals collected from the duplicate jumbo multiplate samplers that were exposed at each of the three station locations (stream habitats) for each of the exposure periods. Mathematical adjustments for laboratory subsampling were also made in these cases as required. However, such refinements were not necessary for those duplicate Hester-Dendy samples and for those single Surber samples that were not subsampled in the laboratory; in these cases, the raw counts on the station-date data sheets already had the required form. About 69% of the Hester-Dendy collections and about 53% of the Surber collections were not subsampled prior to the data enumerations, and about 80% of the Surber collections involved the obtainment of only one sample from a stream on any particular station trip.

The refined square-foot taxa densities (natural substrates) and the refined taxa-individual counts per duplicate sampler (artifical substrates) represent the main macroinvertebrate data base of the inventory, and all of the numbers of this kind collected during the project are presented by sampling station and by collection date in the companion data report (Klarich, et al, 1980) to this publication. As a major data reduction, the taxa density values of each sample were summed to provide for an overall number that describes the abundance of all of the macroinvertebrates that were collected at a stream location on a certain sampling date. In addition, taxa means and overall abundance means were calculated for each of the intensive and accessory stations by averaging, as appropriate, all of the sample data that were collected for that site. The sample abundance values, the station taxa means, and the station abundance means are also included in the data report.

All of the natural substrate densities are presented in the data report on a square-foot basis since this format corresponds with the actual collection area of the Surber sampler that was used during the project. This retention of the actual field sampling area in the early data manipulations is important in terms of calculating certain of the diversity indices as impled by Weber (1973). However, once such diversity measurements have been completed using the actual field data, conversions of macroinvertebrate abundance to metric units can be easily made by simply multiplying the square-foot densities by 10.76 or by 0.108 for numbers per square meter or for numbers per square decimeter respectively. To further refine the study data, all of the density summaries in this interpretive report that deal with the Surber work will possess the more scientifically acceptable, square meter form.

Diversity Measurements

Margalef Index. The major type of data reduction and refinement applied to the project's macroinvertebrate information involved the determination of station and sample diversities. Such expressions are most commonly calculated in the form of single numbers that are positively related to the diversity characteristics of a biotic system; that is, higher numbers are suggestive of the occurrence of a greater biological mosaic within the sampled areas. Thus, the use of diversity indices also provides a relatively powerful and straightforward tool for assessing large quantities of biological data as is the case for the coalfield inventory. Numerous approaches for calculating single-number diversity values are available to researchers as partially reviewed by Wilhm (1967), and two of these techniques were chosen for application to the project macroinvertebrate data. Each of these two

indices have certain inherent strengths and weaknesses, and they both were given somewhat different roles in the project assessments in relation to their different attributes.

One of the diversity measurements utilized in the project was first defined by Margalef (1952), and it is basically a ratio of the number of macroinvertebrate taxa identified in a sample to the total number of macroinvertebrate organisms in the collection. The Margalef index is defined by the following equation:

$$M_s = (t - 1)/\ln N,$$

where M_s is an index value as applied to a single, square-foot sample or to duo Hester-Dendies, t is the number of taxa in a collection, and N is the total number of individuals counted; N is determined as a summation (S.) of the taxa individuals (n_i) in a sample, i.e., N = S. n_i, as noted above. The magnitude of this index can range by definition from zero (one taxa) to extremely large numbers (e.g., up to 144 with 1000 taxa), but in an empirical sense, index values above five are probably quite uncommon in most freshwater, lotic systems because of the limited number of taxa in the natural case. The primary advantage for using the Margalef approach resides in its ease of computation, and because of this feature, this index was individually applied to all of the Surber and Hester-Dendy samples analyzed during the inventory.

The main disadvantage of the Margalef index is found in its lack of sensitivity for distinguishing distributional differences in the numbers of individuals among the sample taxa. This aspect is illustrated in Table 5 which is based on sets of theoretical data that closely correspond to the types of numbers obtained in the southern Fort Union inventory. As shown, a sample having an equal number of representatives for all of its taxa would have the same M_s value as a sample that had one taxa that was overly dominant. Such insensitivity is unfortunate because a more evenly distributed sample would be reflective of a more diverse situation biologically than an unequally oriented counterpart even though they both could have the same $(t - 1)/\ln N$ ratio. Furthermore, Weber (1973) points out that the Margalef type of index is dependent upon the total number of organisms collected which can be an uncontrolled variable in some types of macroinvertebrate sampling. However, this problem can be circumvented to some extent by collecting defined areas in the field and by directly using the associated data in the diversity calculations as suggested earlier. Thus, the Margalef values developed in this study have to be defined as being based on a square-foot area for the natural substrates versus some other sampling option. For the artificial substrates, the Margalef has to be defined as being based on the use of duplicate jumbo multiplate samplers.

Regardless of these difficulties, Wilhm (1967) found that the Margalef approach, from among the several indices that he examined, most effectively detected and distinguished pollutive influences between his different sampling stations. Wilhm's observation, thereby, along with the ease of computation, afforded another justification for the general application of the M_s diversity measurement to the inventory data.

In addition to the single collection M_s values, mean station diversities

Table 5. Comparisons of the Margalef (M) and Shannon-Weaver (SW) diversity indices under different data combinations: large (L), moderate (M), and small (S) numbers of macroinvertebrate taxa and sample individuals plus differing distributions of these individuals among the sample taxa.

Number of Sample Individuals	Number of Sample Taxa	Distribution of Individuals Among the Taxa: Equal(a)	Unequal Extreme(b)	Variable(c)
L = 3000	L = 20	M = 2.37; SW = 4.32	M = 2.37; SW = 0.08	M = 2.37; SW = 3.13
L = 3000	M = 10	M = 1.12; SW = 3.32	M = 1.12; SW = 0.04	M = 1.12; SW = 2.49
L = 3000	S = 4	M = 0.37; SW = 2.00	M = 0.37; SW = 0.01	M = 0.37; SW = 1.52
M = 1000	L = 20	M = 2.75; SW = 4.32	M = 2.75; SW = 0.22	M = 2.75; SW = 3.13
M = 1000	M = 10	M = 1.30; SW = 3.32	M = 1.30; SW = 0.10	M = 1.30; SW = 2.49
M = 1000	S = 4	M = 0.43; SW = 2.00	M = 0.43; SW = 0.03	M = 0.43; SW = 1.52
S = 200	L = 20	M = 3.59; SW = 4.32	M = 3.59; SW = 0.86	M = 3.59; SW = 3.13
S = 200	M = 10	M = 1.70; SW = 3.32	M = 1.70; SW = 0.41	M = 1.70; SW = 2.49
S = 200	S = 4	M = 0.57; SW = 2.00	M = 0.57; SW = 0.14	M = 0.57; SW = 1.52

(a)In the equal case, all of the sample taxa have the same number of individuals. (b)In the unequal extreme case, all of the sample taxa but one have only a single representative while one of the taxa has the remaining individuals. (c)The variable case generally coincides with the theme most commonly observed in nature with a gradually decreasing number of individuals per taxa as follows:

For 20 taxa--25%, 19%, 16%, . . . 0.2%;
For 10 taxa--40%, 22%, 15%, . . . 1.0%;
For 4 taxa--56%, 25%, 17%, and 2%.

were calculated as an average of the sample Margalefs ($\overline{M}_s$) obtained from that site. In addition, an overall station diversity (M_o) was computed by using the following equation:

$$M_o = (\overline{t} - 1)/\ln \overline{N},$$

where $\overline{t}$ and $\overline{N}$ are the means of the sample taxa numbers and the total sample individuals respectively. The $\overline{M}_s$ and M_o values tend to be generally similar, although $\overline{M}_s$ is often slightly higher than M_o in those cases where there is a weighting effect by a few collections that have an extremely high and/or unusually low number of total individuals.

Shannon-Weaver Index. The other diversity index utilized in the inventory was developed by Shannon and Weaver (1964), and the main disadvantage of the Shannon-Weaver (SW) application resides in the difficulty of its calculation. The difficulty in this instance pertains to the index's relatively lengthy computation time requirement. This feature is illustrated by the following computing equation developed by Lloyd, et al (1968):

$$SW = C/N\ (N \log N - S.\ n_i \log n_i),$$

where SW is an index value, C is a constant (3.321928), N is the total number of individuals counted, and n_i is the number of representatives for the i^{th} taxa. Like the Margalef, the SW index can range from zero (one taxa) to fairly large values (e.g., up to 10.0 with 1000 taxa and 2000 total organisms), but SW numbers above five are also probably quite rare in most freshwater environments.

The SW index has been recommended by the Environmental Protection Agency for use in benthic macroinvertebrate evaluations (Weber, 1973), and because of this fact and for other reasons, it has been applied in concert with the Margalef index to the natural and artificial substrate data of the study. But because of the computational time factor, the SW index was used only in association with the mean n_i and N data that were obtained from the intensive and accessory stations and not in conjunction with the individual samples. As a result, the SW values are most closely equivalent to the Margalef, M_o representations within the context of this particular project.

One of the main advantages for applying the SW index to diversity assessments resides in its capacity for detecting variations in the distribution of numbers of individuals among the sample taxa, and such a sensitivity is totally absent in the Margalef approach. This type of biological shift should also be recognized as a component of overall diversity, and the differences between the two indices in this regard are illustrated in Table 5. These data show a sharp decline in SW values between the "equal" and "unequal extreme" kinds of distributions while the Margalef remains unaltered through these same comparisons. However, both of the indices are reflective of taxa richness where the index values decline in association with a drop in taxa numbers, although the Margalef appears to be a more responsive indicator of this type of change in community structure.

A further difference between the SW and M_o indices is found in the influence of total organism numbers on the index values. The Shannon-Weaver approach is independent of this variable, as shown in Table 5, when taxa numbers

and when individual distributions among the taxa are held constant. The Margalef, in contrast, is affected in this way and shows an increase in diversity as total numbers decline in the face of an unchanged number of taxa. For this reason, and because of the observation discussed above, the M_o expression seems to be a more sensitive detector of alterations in taxa richness than the SW index which points to another advantage for using the Margalef form. But at the same time, an index like the Shannon-Weaver that is independent of total collection numbers possess the advantage of having a broader comparative range than the dependent ones in the sense of not being fettered by the need for accessory definitions that prescribe the kind of comparison that can be made. In other words, the SW index is not restricted by a square-foot type of comparative criteria as is the case of the Margalef, and the SW, as a result, can be used to compare sets of data that were collected by separate methodologies. In this project, for example, the M_o index cannot be effectively used in comparing the artificial substrate and the natural substrate data because of the differences in sampling techniques and the differences in sampling definitions, although the SW index is amenable to such an application.

In any event, through the use of both of the indices in this inventory, their individual weaknesses should be counteracted to some degree by the strengths of the other index, and this should provide a better description and analysis of the biological characteristics of the study area waters than would have been obtained with the use of only one of the indices alone.

Equitability. As a spin-off from the Shannon-Weaver calculations, a third index termed "equitability" was determined from the project data to afford further insights into status of the streams' benthic biota. Equitability is defined in Webster's dictionary (Guralink, 1976) as a condition of fairness or justness in a system, and the application of this definition in an ecological fashion is defined as the ratio between the number of taxa actually counted in a sample, providing for a specific SW diversity value, and a theoretical number of taxa that would have been obtained for that same diversity value if the macroinvertebrate association in the sample had happened to conform exactly with MacArthur's (1947) broken stick model. An ecological expression of equitability, thereby, is made in the form of a single index number that can be calculated by using the following equation:

$$e = t'/t,$$

where e is the equitability value, t is the number of taxa observed in the collection, and t' is the theoretical number of taxa for the related SW index number relative to MacArthur's model. These t' values have been computed by Lloyd and Ghelardi (1964), and they have been tabulated in an Environmental Protection Agency (EPA) biological methods manual (Weber, 1973).

Equitability values typically range between zero and one where a near zero value shows a poor correspondence to MacArthur's model and a lack of fairness in the distribution of individuals among the taxa; i.e., the distributions are highly unequal a la the example in Table 5. An equitability of one, in opposition, shows a close correspondence to MacArthur's model, a high degree of fairness in the distribution of individuals, and a closer correspondence of the macroinvertebrate association to the type of taxa-individual number distributions that are commonly found in nature. In some

instances, equitabilities greater than one can be obtained, and these cases prescribe a situation where " . . . the distribution in a sample is more equitable than the distribution resulting from the MacArthur model (Weber, 1973)." This type of equitability most commonly occurs in samples with a relatively small number of individuals but with several taxa representatives, although equitabilities greater than one can also be seen in a few unique situations where a large number of individuals are distributed quite evenly over a fairly large number of animal groups.

Many of these equitability features are reflected by the contrived data that are presented in Table 5 where the "unequal extreme" case demonstrates markedly low e values ranging from 0.003 to 0.005 which might be expected because of the extremely unfair distributions. The "equal" case and the "variable" case, however, afford much higher values, from 1.43 to 1.48 and from 0.63 to 0.84 respectively, in accord with the greater fairness of these distributions.

The usefulness of the equitability application resides in the fact that environmental stress tends to reduce the magnitude of this index in rough proportion to the degree of the impact, and this feature provided the justification for applying this index to the project's macroinvertebrate data. Since the equitability determinations hinge on the availability of SW diversity values, e numbers could only be calculated on a station basis using the taxa means and the mean total abundance data that were made available for a site; equitability, therefore, could not be established for the individual samples.

Index Correlations. Since both the Margalef and the Shannon-Weaver diversity indices were to be used to judge the biotic status of the study area streams, it was hoped that a definite and positive relationship might be found between the two indices relative to their computations on the same sets of data. But the summaries in Table 5 point to the possibility that this requirement might not be borne-out in those cases where the nature of the data results in wide discrepancies between the SW and M_o values of a large number of paired comparisons. Although this conclusion might apply to some systems, even with the occurrence of fairly distinct inter-index differences, as is exemplified by the data in Table 5, positive correlation coefficients can still be obtained between the two indices that demonstrate a statistical significance. For example, r = 0.39 for the Table 5 data with significance at about 5% for the 27 pairs. Since the contrived data in Table 5 were developed to illustrate a fairly extreme variation in the numbers that are used to make the diversity calculations, the positive correlation that was obtained in this instance suggests that at least a weak relationship between SW and M_o can be generally expected from the real world regardless of any major differences that might be found between the index values because of taxa number, total organism number, and individual distributional variations among the actual macroinvertebrate samples.

As a further observation along these lines, the strength of the correlation between the two indices is enhanced if the distribution of individual numbers among the taxa is held constant. This feature is also illustrated by the Table 5 data as follows: equal case--r = 0.93, unequal case--r = 0.76, and variable case--r = 0.92 with nine data pairs in each group. All of these correlation coefficients are also significant at less than 5%, and this

significance and the high coefficient of the variable case prove to be particularly important because most of the macroinvertebrate samples would be expected to have this type of distribution in accord with MacArthur's model. On this basis then, a highly significant and relatively strong positive relationship can be expected between SW and M_o for most sets of macroinvertebrate data with both of the indices than acting together as suitable indicators of biotic diversity, producing the same interpretive conclusions.

If a SW and M_o correlation on a group of data should happen to be less than 0.92, this would indicate that some of the samples had non-variable or non-broken stick kinds of distributions that would tend to increase SW and M_o differences and cause reductions in the correlation coefficients. For example, a correlation computation on the variable plus equal data in Table 5 with 18 data pairs results in a somewhat lower coefficient ($r = 0.81$) than the correlation on the variable case alone. A more extreme case is illustrated by the correlation on all of the Table 5 data.

Mixed-Index Interpretations. The above discussion hints at the feasibility of using the relationships between the different diversity indices as an interpretive tool for assessing the macroinvertebrate data in addition to using the magnitudes of the indices *per se*. One example of this option was put forth earlier where low M_o/M_s ratios for a station point to the collection of some samples with unusually low or high numbers of total organisms. The SW/M_o ratio, in turn, can be employed in other kinds of interpretations.

As indicated by the data in Table 5, a low SW/M_o ratio that is well below unity points to the occurrence of an extremely unequal distribution of individual numbers among the sample taxa where a few of the animal groups are excessively abundant. These kinds of collections would also have a low equitability. But if the SW/M_o ratio is relatively high and well above one, or at least close to one, then an equal or a more variable type of distribution of individuals might be anticipated with high equitabilities and with none of the taxa being overly dominant in the benthic biota. For the most part, therefore, the SW values that are obtained from field data are typically greater than the M_o values when computed on the same sets of samples because the variable or broken stick distributional format is quite common in nature. Furthermore, the positive differences between SW and M_o become more pronounced as the individual distributions approach a greater taxa equality, especially when the number of sample taxa and the number of total macroinvertebrate organisms remain constant. The SW/M_o ratio, thereby, tends to increase above unity in response to this kind of alteration. This latter feature ultimately provides another interpretive lever that can be used to judge distributional characteristics in certain of the project's data assessments.

The Shannon-Weaver/Margalef ratio also shows an increase as the total number of collected taxa decline, and as a result, SW/M_o values above 1.9 are generally indicative of a small number of sample taxa in the vicinity of ten or less that have equal or variable distributions. But if the number of sample taxa are relatively high (near or above twenty), then the SW/M_o values are typically less than 1.9 but greater than 1.2, and the higher values

between 1.6 and 1.9 within this range point to a more equal type of individual distribution among the taxa while ratios between 1.2 and 1.6 point to the more variable form as described in Table 5. However, these kinds of SW/M_O interpretations become restricted and increasingly invalid as the number of taxa happen to decline because of the tendency towards higher SW/M_O values in these cases regardless of the distributional patterns. These interpretations also become invalid with the collection of a relatively small number of total organisms (around 200) since SW/M_O ratios show a marked decrease in conjunction with a drop in total individuals; i.e., differences between the two indices are much less when a small number of specimens are collected. But in almost all of the cases, SW/M_O ratios that are significantly below unity indicate the likelihood of a distinctly unequal distribution of individual numbers among the different macroinvertebrate groups.

Single-Index Interpretations, Shannon-Weaver and Equitability. Although the SW/M_O determinations have some applications to macroinvertebrate community assessments, the main interpretive focus of the inventory of course, resides with the M_S, $\overline{M}_S$, M_O, SW, and equitability indices themselves where the lower magnitudes of an index are suggestive of reduced biological diversities and the action of some mode of environmental stress. In the case of equitability (e), EPA biologists (Weber, 1973) have found that unstressed systems typically have e values above 0.5 and generally in the area of 0.6 to 0.8. But these same researchers have also found that even slight levels of degradation will act to reduce equitability below the 0.5 level with the more severely affected systems having e values in the 0.0 to 0.3 range.

In a similar fashion, Wilhm (1970), after reviewing the study data from a variety of polluted and unpolluted waters, observed that Shannon-Weaver index values between three and four were typically obtained from unstressed situations while SW values between zero and one were typically obtained from polluted aquatic environments. These SW numbers and the equitability numbers listed above can be used as reference criteria by which to assess the diversity values that were computed for the macroinvertebrate samples collected during this project in relation to any stress factors such as salinity that might be affecting the benthic associations of the study area streams. However, the consideration of two intra-project problems and two general corollaries should preface these applications in terms of potentially amending or refining any of the conclusions that are drawn from the diversity data.

One of the two corollaries relates to Weber's (1973) observation that equitability is a more sensitive indicator of environmental stress than SW diversity, and this feature should be kept in mind when any interpretive discrepancies arise between the two measurements. In these cases, equitability should probably be given a greater weight than diversity in judging the nature of the environment, particularly in borderline situations. As a second corollary, Weber (1973) points out that the e and SW values are not very meaningful if the total number of macroinvertebrate organisms collected from a stream station lie below one-hundred. But this requirement should not be a factor in this inventory since the SW and the e computations were based on the mean station data where more than one-hundred average individuals were collected from all of the sampling sites.

One of the two problems referred to previously stems from the less than ideal level of taxonomic resolution that was developed during the inventory. The reasons for this reduced resolution have been discussed earlier, and in spite of this factor, it is felt that an adequate and best resolution was obtained within the capacity of the study for most of the interpretive requirements. Nonetheless, some thought should be given to the fact that a reduced resolution can lead to an underestimation of diversity index values which could result in false interpretations concerning the stressed nature of an aquatic system. But in the main, such judgemental errors in relation to the use of Wilhm's (1970) SW interpretive guidelines are not foreseen as a major difficulty in this inventory for the reasons cited below.

In the first place, the average number of taxa per sample in this project (near thirteen) was found to be equivalent to a SW value of 3.20 if MacArthur's (1957) community structure model is followed by the macroinvertebrate associations of the study area streams, and this number is above Wilhm's upper stress criteria. Furthermore, even with the occurrence of only a 50% taxonomic resolution in the inventory, the inability to recognize thirteen additional taxa above those identified, or 26 total, which would decrease the index from 4.15 to 3.20, does not alter any of the fundamental conclusions that could be made in conjunction with Wilhm's guideline. Thus, the interpretation of the relatively high and the very low SW index values of the project were judged to be fairly straightforward with reference to Wilhm's findings, especially if total taxa numbers are relatively large.

The recognition of less than eleven taxa at a 50% resolution, however, presents a somewhat different picture along these same lines in providing an index discrepancy on the order of 3.30 to 2.37 under the broken stick model, and this difference cuts across Wilhm's criteria. Eight recognized taxa versus the sixteen possible were used in this particular example. This type of error, therefore, could bias the subsequent conclusions in a negative fashion through an underestimation of true diversities. As a result, any SW diversity values of the project that are based on less than eleven taxa but on more than five taxa and that are found within the two to three range are best viewed as occurring in a middle ground or gray area where a mild environmental stress might be operating but where an inadequate taxonomic resolution could also influence the interpretations.

As an essential corollary observation to this problem, since the SW index determinations were made on a station basis using mean data rather than on a single sample basis, the total number of taxa involved in most of the SW calculations were generally much greater than eleven, and this feature undoubtedly negates the <100% resolution difficulty to a considerable degree. In addition, if the taxonimic resolution of the study happened to be considerably greater than 50%, then the importance and extent of this gray interpretive area would be much less significant. Unfortunately, no methods were available by which to establish the actual resolution levels of the inventory; the 50% projection was simply selected as a convenient midpoint number, although it is probably a fairly reasonable estimate of this factor.

In light of the previous discussions, the classification system

presented below was developed as a means of evaluating the SW diversities that were calculated for the macroinvertebrate collections of the project.

SW > 3.00: Class A--Values in this range indicate an unstressed system and a healthy benthic biota with the interpretations becoming more valid as the index approaches and exceeds four.

2.00 to 3.00: Class B--If six to ten taxa are involved in a diversity computation, then the index values in this range denote a borderline interpretive region because of the likely occurrence of a reduced taxonomic resolution; otherwise, such values could point to the action of a fairly mild environmental stress, particularly at the lower numbers within this range.

1.00 to 2.00: Class C--Values in this range indicate the likely occurrence of a moderate environmental stress of some kind with the interpretations becoming more valid as the index approaches one.

0.0 to 1.00: Class D--Values in this range indicate the definite occurrence of an environmental stress that is probably quite extreme in character, and these interpretations also become more valid at the lower numbers as the index approaches zero.

Single-Index Interpretations, Margalef. Another problem that should be addressed in terms of interpreting the diversity index values relates to the evaluations of the Margalef (1952) expressions since the SW classification scheme presented above is not directly applicable towards judging the Margalef numbers. This is due to the fact that although the Margalef index appears to be closely related to the Shannon-Weaver, the former typically has a lower magnitude than the latter on the same sets of data, and this is complicated by the observation that these inter-index differences can vary depending upon the distributional nature of the data. But if a variable or broken stick distribution is assumed for the benthic faunal associations, the theoretical numbers in Table 5 can be used to estimate an overall correction factor with which to adjust the SW criteria to a Margalef format. This adjustment is feasible because these tabulated values simulate the range of typical taxa numbers and typical total individual numbers that were obtained from the macroinvertebrate samples collected from the project region streams.

The average SW/M_o ratio from the Table 5 data for the variable case is equal to 1.51 which indicates that the typical Margalef value stands at about two-thirds of the corresponding SW number for the entire gamut of possible SW/M_o variations within MacArthur's model. This mean fraction was then used to correct the four SW stress criteria to values that can be applied to the Margalef index. The Margalef classification system can be summarized as follows (where M_x represents any one of the three M_s, $\overline{M}_s$, and M_o applications): $M_x > 2.00$ is generally equivalent to Class A; 1.35 to 2.00 is generally equivalent to Class B; 0.67 to 1.35 is generally equivalent to the Shannon-Weaver Class C; and 0.0 to 0.67 is generally equivalent to

Class D. These various adjusted guidelines can then be used for evaluating the Margalef index numbers that are calculated for the project's macroinvertebrate samples.

Reduced taxonomic resolutions can also bias the Margalef index in a negative fashion as well as the Shannon-Weaver, and the effect is greater for the Margalef because of its basic design; i.e., the Margalef is more sensitive to changes in taxa richness. For example, a 50% resolution with MacArthur's model will reduce the SW from 3.30 to 2.37 in the case of eight identified taxa as noted previously, but an identical resolution would decrease the Margalef from 2.21 to 1.03 for the same taxa numbers. In addition, this negative effect cannot be discounted as easily for the Margalef as it was for the Shannon-Weaver through the calculation of station means. The only rationalization, thereby, resides in the demonstration of a close relationship between the two indices and in the hope that the reduction in project resolution was not adequate to bias the Margalef to a sufficient level so that the calculated values consistently spilled under one of the correct reference guidelines listed earlier. This occurrence would result in false conclusions concerning the status of the benthic biota, but it does not appear to have developed into any kind of major problem for the inventory. Nevertheless, the SW will be judged as the most trustworthy of the two biotic indicators in the case that any interpretive discrepancies should happen to develop between the two indices because of this factor.

Percentage Similarity and Other Calculations

The faunistic similarities and dissimilarities of the macroinvertebrate associations in the various study area streams were determined by applying a percentage similarity (PS) computation to the mean taxa numbers that were obtained for the different sampling stations; this application was not directed to the individual samples. The PS index used in these assessments was defined by Whittaker and Fairbanks (1958), and it involves station comparisons on a paired basis using the percent relative abundance values that have to be calculated for some of the taxa at each of the two stations being compared. Percent relative abundance (PRA) is defined as follows:

$$PRA_{Ax} = 100\ (n_{Ax}/N_x),$$

where PRA_{Ax} is a percentage value for taxa A at station x, n_{Ax} is the mean number of representatives for taxa A at station x, and N_x is the mean total number of macroinvertebrate individuals at the station. With the availability of this PRA data for any combination of two sampling sites, a similarity value can then be calculated between the two with the following equation:

$$PS_{xy} = 100 - 0.5\ (S.\ /PRA_{ix} - PRA_{iy}/),$$

where PS_{xy} is the percentage similarity value for the two stations of interest (x and y), where S. denotes a summation operation, where the slashes define an absolute value, and where PRA_i is the percentage value of the i^{th} taxa at one or the other of the stations undergoing the comparison.

This PS index ranges from a maximum value of 100% which is indicative of a perfect faunal similarity to a minimum value of zero which points to a

complete taxonomic difference in the macroinvertebrate specimens of any two sampling sites. In this study, PRA's were calculated only for the six most abundant taxa at a station, and the PS comparisons were made on this basis. Such a limitation proved to be essential in order to avoid excessive computation times, and it was feasible because the six top ranked taxa provided an average of 94% of the total macroinvertebrate abundance. But to achieve an accounting balance through all of the PS values, the remaining percentage, i.e., 100% minus the summed PRA's of the six most abundant macroinvertebrate groups, was treated as a single station taxa in the PS computations. However, since the leftover percentage was typically quite small, this manipulation did not sufficiently alter the PS number of a paired comparison to distort the similarity interpretations.

The similarity index described above is both qualitative and quantitative in character in its dependence upon both the kinds of taxa present and their relative abundances. Because of its quantitative component, two stations could have the same top ranked taxa but still show a low PS similarity if the PRA's of the taxa should happen to be quite different. As an extreme example, PS values as low as 0.6% could be obtained between two sampling sites even with identical taxa, and this feature acts to narrow the interpretive spectrum of the PS index to some degree. To provide for a second assessment option in relation to the similarity evaluations of the inventory, a qualitative type of similarity index (QS) without a quantitative aspect was developed within the project for application to the macroinvertebrate data. This index has the advantage of not being dependent upon the taxa PRA values but only upon the kinds of taxa that might have been collected at the two stations being compared. The QS expression is described by the following equation:

$$QS_{xy} = (100)\ (2M - X - Y)/(2M + X + Y),$$

where QS is a taxonomic similarity value between the two sampling sites (x and y), where M is the number of taxa that are found at both of these stations, where X is the number of taxa that are found at only one of the locations (x) while being absent from the other (y), and where Y represents the computational mirror image of the X variable.

The QS index ranges from + 100 to -100 with the first value showing a total taxonomic agreement and with the latter showing a complete taxonomic difference between the two comparatives. A QS of zero, in turn, points to a 50% faunistic similarity while values of + 50 and -50 indicate the 75% and 25% levels of similarity respectively. Because of the relative ease in developing the data that are required for this index, a QS value can be readily calculated from all of the taxa that are observed at the two stations of interest without the need for a data reduction as is the case for the PS computations.

In addition to diversity and similarity, other forms of data manipulation were also performed during the assessment phase of the inventory to additionally refine and reduce the data, to highlight certain features of the benthic communities, and to afford the basis for making particular comparisons. The technique that was developed for quantifying the distribution and abundance aspects of the different macroinvertebrate organisms through the definition and calculation of single taxa importance values provides one example of these

additional manipulations. Another example relates to the development of an expression that can be used to illustrate the seasonal density changes of the macroinvertebrate associations in the study area streams. These two applications and others along these same lines were conceived and utilized entirely within the context of this study and in relation to the characteristics of the study area, and they will be described later in this report in conjunction with the discussion that details a particular result of the inventory. This approach will provide the reader with a clearer understanding of the reason and intent of the various manipulations.

Statistical Applications

Summary Statistics. Both the summary and the test kinds of statistical applications have been directed towards the data of this biological inventory. The summary type was utilized to reduce and refine the data while the test statistics were employed to assist in the project's data assessments. The calculation of mean values for the different sets of numbers represents the major summary application as described earlier, but in addition to the mean statistic ($\bar{X}$), minimum-maximum values, medians, standard deviations (s), and percent deviations were also used to congeal the salinity and macroinvertebrate data of the study into presentable units for the purpose of illustration in this report.

The minimum-maximum numbers noted above provide a definition of the range of a data array while the medians identify a particular point within this array, a midpoint, where 50% of the observations fall above and below this value. The standard deviations, in turn, give an indication of the variability of the array, and the percent deviations--$(100)(s/\bar{X})$--reference the magnitude of this variability to a measure of the central tendency of the data set so that comparisons of the variability component can be directly made. In terms of intepretation, percent deviations that are less than 30% and close to zero are suggestive of a fair degree of constancy within the data array and a low variability while percent deviations that approach and exceed 100% are suggestive of a high degree of variation and a marked inconsistency in the numbers of the array.

As a further observation along these lines, a similarity in the mean and median values of a data set indicates that its variability, whether high or low (high or low percent deviations), is spread quite evenly above and below a central point. However, if a mean and the associated median are quite different, then this feature indicates that the unusually high or low values of a few unique observations tend to weight the mean towards the high or low end of the array. Furthermore, with the mean considerably less than the median, the unique observations would have relatively low magnitudes, but with the mean considerably greater than the median, then the unique observations would have relatively high values in relation to the rest of the numbers. These mean-median relationships can also be used to help describe the nature of the study data in conjunction with the other statistical summaries.

Test Statistics. The main statistical test of the project involved the calculation of correlation coefficients to establish the actuality of and to describe the nature of any relationships that might have occurred between select pairs of study variables. One example of this application

was presented previously where correlation coefficients between the Shannon-Weaver and Margalef indices were determined using the theoretical sets of data in Table 5. Similar correlation computations will be directed to the index values that have been obtained from the actual study data. However, the principal correlation work will examine the relationships between stream salinity as specific conductance and macroinvertebrate diversity, and it will also consider the relationships between stream salinity and macroinvertebrate density or abundance. These correlation coefficients will be computed on a sample and on a station basis for both the natural and the artificial substrate collections, and the Margalef will be used as an estimator of the Shannon-Weaver index in these calculations. If any of the coefficients can be shown to be statistically significant at some reasonable level of probability, then a regression analysis can be applied to the same data pairs in order to obtain the equations (slope and Y-intercept) for a linear graph between salinity and diversity or density. Such equations will afford some predictive capabilities for evaluating the effects of salinity on the macroinvertebrate associations of the coalfield area streams, and this activity will fulfill one of the major objectives of the inventory.

A model TI-55 calculator (Texas Instruments Incorporated, 1977) was used to make the correlation-regression computations, and Lentner (1968 and 1969), Walpole (1968), and Hoel (1966) were utilized as the statistical references for these applications. The same statistical publications were used to reference the analysis of variance (ANOVA), multiple comparison, chi-square, and t-test evaluations that were also directed to certain segments of the study data. Along with the correlation and regression analyses, this listing summarizes the major kinds of test statistics that were employed in the project. These tests and the various other kinds of tests of a miscellaneous nature that were used in the inventory assessments will be described more fully later in this report at the point where they are used to assess a particular feature of the study results.

RESULTS AND DISCUSSION--STREAM SALINITY LEVELS

BACKGROUND FEATURES

Definition and Means of Measurement

The concept of salinity originally evolved in its oceanographic applications, and in this sense it has a rather complex definition and is closely related to total solids and to the chloride concentration of a marine sample which is the dominant ionic constituent of these particular systems. In freshwater situations, the term salinity and a sample's total dissolved solids concentration are largely equivalent for most practical purposes where the latter expression consists of a water's dissolved ionic salts, its dissolved organic matter, and its dissolved and nonionic inorganic materials (EPA, 1976).

Salinity in its freshwater applications is most accurately determined as a total filterable residue at some prescribed drying temperature as outlined in Standard Methods (American Public Health Association, et al, 1975). As an alternative, salinity can be approximated as a sum of the dissolved ionic constituents if the appropriate chemical analyses have

been made. This second approach will afford only a slight underestimation of true salinity if the dissolved organic and nonionic inorganic concentrations are at low levels as is observed for many of the freshwaters. However, both of these methodologies require a fair expenditure of laboratory time and effort to secure the requisite data. In view of the large number of water samples that were to be assessed for salinity in relation to the biological collections of this study, specific conductance (SC) was used as a surrogate measure of this important parameter because of the extreme ease of analysis. The methods that were adopted for the SC assessments have been described previously.

Since SC is a measure of the capacity of a water to conduct an electrical current which is proportional to the concentration of the ionized constituents, SC, thereby, cannot detect the presence of the nonionized materials. As a result, the use of SC as an estimate of salinity first assumes that these unmeasured dissolved materials are at low concentrations. Secondly, the assumption is made that the SC applications actually describe the concentrations of the ionic constituents in a fairly accurate fashion, and this is important because these ionized substances make the major contribution to a water's salinity level. Therefore, the demonstration of a close relationship between dissolved ionic solids (DS) and SC should precede any subsequent discussions of salinity effects.

Since DS determinations as the sum of individual constituents have been made during the project in association with 57% of the SC measurements, the reality of a significant and positive DS-SC relationship in this inventory can be demonstrated by correlating the sample DS and the corresponding SC values that have been tabulated in the companion data report (Klarich, et al, 1980). A high correlation coefficient was obtained from this evaluation, r = 0.989, for the 180 data pairs that are listed in the companion report, and this coefficient is statistically significant at much less than 1%. In addition, high coefficients were also obtained on a station basis in those cases where an adequate number of DS-SC pairs were available by which to run a meaningful correlation. As examples, r = 0.922 with nine pairs for Indian, r = 0.998 with eight pairs for TR-PBB, r = 0.783 with eleven pairs for LHWC-B, r = 0.996 with eight pairs for UOtr-O, r = 0.982 with ten pairs for the Armells Creek samples, and so on. All of these coefficients are also significant at less than 1%. These results indicate that SC was an adequate estimator of the DS concentrations of the inventory streams, and SC also appears to be a suitable indicator of the salinity levels of these waters if the first assumption mentioned above actually holds true for the study area streams as it does for many of the freshwaters.

Reference Criteria Descriptions

Salinity is an important water quality parameter when at high concentrations because of its adverse effects on most off-stream water uses such as public supply and irrigation. As a result, this parameter has undergone intensive study to describe its influence on these different off-stream uses, and from these many investigations, various reference criteria have been established that denote the levels where its negative effects on a particular water application can first be observed. In essence then, a water having salnity concentrations in excess of a reference

level should not be applied to the associated use. These general reference criteria have been published and described by federal and state agencies starting with the Public Health Service (1962) and the California State Water Resources Control Board (McKee and Wolf, 1963) and culminating with a series of EPA publications (National Technical Advisory Committee, 1968; Environmental Studies Board, 1973; and EPA, 1976). Salinity is additionally important from an instream perspective, and these same publications also consider this aspect of its overall water quality implications.

The main action of salinity as an instream biological factor is found in the osmotic pressure that the dissolved materials exert on the aquatic organisms. However, this observation has to be prefaced by the requirement that these dissolved substances are largely innocuous, i.e., nontoxic, in character. Such osmotic pressures influence the internal water status of the organisms, and these pressures increase in concert with an elevation in the salinity levels of an aquatic system. High salinity concentrations, high osmotic pressures, and a high water stress component ultimately preclude the establishment and survival of those plants and animals that demonstrate a relatively low tolerance to this water quality and physical condition.

Most of the instream salinity research has been directed towards the fishery, and one study (Rounsefell and Everhart, 1953) concluded that the upper tolerance limits for most freshwater fish probably lie between 5,000 and 10,000 mg/l depending upon the species and an individual's prior acclimatization. Ellis, et al (1946), in turn, has observed that a good mixed fish fauna is usually not found in waters of the western plains with SC values greater than 2000 micromhos. But for the most part, the specific effects of salinity on the different fish species are not well known. In addition, this lack of knowledge is much more pronounced for the other types of aquatic organisms such as the benthic macroinvertebrates, and this feature provides one of the principal reasons for undertaking the biotic inventory of the southern Fort Union streams.

As a relatively broad observation on the relationships between salinity and the aquatic biota in general, Hart, et al (1945) has determined that 95% of the inland waters of the United States which support a mixed biota had salinity concentrations less than 400 mg/l (about 500 micromhos). Furthermore, the National Technical Advisory Committee (1968) recommended that salinity should not be increased to levels that exceed 1500 mg/l as sodium chloride in systems where a diversified animal association is to be protected; otherwise, salinity increases should be limited to one-third of the naturally occurring concentrations. McKee and Wolf (1963) made a similar recommendation in suggesting that salinity values below 2000 mg/l of DS, which is roughly equivalent to a SC of about 2400 micromhos, should not significantly interfere with the viability of freshwater fish and other forms of aquatic life. The DS numbers developed by the National Technical Advisory Committee (NTAC) and by McKee and Wolf might be used as very general criteria by which to judge the instream salinity status of a lotic water in relation to its aquatic biota. That is, as salinity levels increasingly exceed 2000 mg/l, more severe biological effects might be expected. But because of the widely variable influences of this parameter on the different organisms, the more recent water quality criteria publications (Environmental Studies Board, 1973; and EPA, 1976) have not

set forth any specific guidelines of this kind. Instead, they suggest that " . . . bioassays and field studies can determine the limits that may be tolerated without endangering the structure and function of the aquatic ecosystem." This coalfield stream inventory, thereby, might be construed as one of these requisite field studies.

DATA REVIEW

Study Area Aspects

Specific conductance readings were taken from 315 water samples (Table 3) collected from the study area streams through a two-year, 1978 to 1979 period, and all of these data are presented on a station and collection date basis in the project data report. Of these SC analyses, 1.9% were completed in March and April, 6.7% in May, 11.1% in June, 15.2% in July, 27.3% in August, 17.5% in September, 7.6% in October, and 11.7% in November. In addition, three samples (1.0%) were collected during the winter (mid-February). Therefore, the bulk of the collections were obtained during the biologically important, warm weather-low flow season, although some samples were secured during all of the seasons and during most of the months to allow for seasonal comparisons. Table 6 provides a statistical summary of these SC data for each of the sampling sites. As indicated, a larger number of water samples were collected from the intensive than from the accessory stations because of the greater sampling frequency in the first case, and as a reminder, not all of the sites listed in Table 6 were sampled for the macroinvertebrates (see Table 1). In addition, the supplemental salinity data that are available from the USGS (1979b, 1980, and 1981) for some of the locations in Table 6 have not been included in this tabulation.

As indicated by the minimum-maximum values in Table 6, the waters of the southern Fort Union region demonstrated a wide variation of salinity levels on a study area and sample basis, ranging from a low of 239 micromhos (umhos) at the TR-ShD site during the early summer to a high of 11,000 umhos at the UHWC-D station during the early fall. The range defines a 46-fold extreme difference in this parameter. However, the 11,000 reading represents a unique outlier that was obtained from an extreme upstream location, and a 329 to 8700 range in SC provides a more accurate description of salinities in the main core of the project area. Natural substrate macroinvertebrate samples were actually collected at salinities as low as 329 umhos and as high as 6400 umhos, providing a nineteen-fold difference, and a smaller eleven-fold difference becomes evident on a mean-median station basis for the intensive and accessory sites, ranging from about 540 umhos at the TR-ShD station to about 5900 umhos for Deer Creek. The artificial substrate work at the intensive sites was conducted through a somewhat narrower range between 600 and 4900 umhos, affording an eight-fold difference, but in all instances, these extreme study area differences in salinity as well as many of the station-to-station differences were much greater than the one-third increase in this parameter that was recommended by the NTAC (1968).

A SC mean for the 42 sampling sites listed in Table 6 was calculated at 2433 umhos, and an average of the medians in this table was found to

Table 6. Salinity characteristics of the study area streams expressed as specific conductance (micromhos per centimeter at 25 C).

Station Symbol	Number of Readings	Minimum Value	Maximum Value	Mean Value	Median Value	Standard Deviation(s)	Percent* Deviation
URsb-K	21	721	950	876	882	51.3	5.9
Pond-K	0	--	--	--	--	--	--
MRsb-C	6	1095	1260	1202	1215	60.1	5.0
LRsb-R	5	1125	1455	1341	1400	139.3	10.4
Indian	9	650	728	684	688	26.2	3.8
Davis	4	1530	2450	1929	1868	414.8	21.5
Muddy	6	1410	1700	1540	1546	101.0	6.6
LameDr	6	875	1032	976	996	60.2	6.2
Cow-C	1	--	--	5760	--	--	--
TR-ShD	8	239	640	507	565	153.5	30.3
IDitch	1	--	--	582	--	--	--
Ash	5	1275	1653	1550	1600	155.8	10.0
Youngs	6	782	1352	1040	1001	209.8	20.2
TR-PBB	21	270	1030	642	648	188.6	29.4
Sqrrl	15	1365	3400	2204	2210	540.4	24.5
Deer	5	5450	6100	5840	6000	315.0	5.4
Canyon	6	1560	1654	1610	1608	34.8	2.2
PrDog	5	1580	1879	1724	1720	108.1	6.3
Bull	3	1640	1884	1788	1839	129.8	7.3
CHS	1	--	--	480	--	--	--
Cook	4	1730	1880	1818	1830	67.5	3.7
Logging	5	838	1125	961	958	107.9	11.2
Beaver	6a	2670	5000	3175	2805	899.4	28.3
Beaver	5b	2670	2925	2810	2805	109.3	3.9
UHWC-D	22a	3320	11,000	4706	4210	1625.1	34.5
UHWC-D	21b	3320	6100	4406	4200	835.3	19.0
LHWC-B	25	2580	4100	3186	3200	399.7	12.6
Stroud	3	2680	2850	2787	2830	92.1	3.3
Lee	1	--	--	3490	--	--	--
EFHWC	19	1165	1390	1321	1320	49.1	3.7
Bear	4	3700	4066	3912	3941	170.2	4.4
UOtr-O	8a	2014	6400	3514	3347	1266.0	36.0
UOtr-O	7b	2014	3533	3101	3314	531.8	17.2
Cow-O	3	462	523	497	506	31.5	6.3
LOtr-A	22	2250	3310	2899	2900	253.4	8.7
Pmpkn	11	478	8700	3285	2100	2854.2	86.9
Mizpah	10	900	3700	2326	2435	1113.0	47.8
EFArm	3	4200	6400	5080	4640	1164.1	22.9
WFArm	4	4080	6000	5320	5600	847.9	15.9
MArm-C	2	5200	6400	5800	5800	848.5	14.6
LArm-F	6a	571	5200	3963	4500	1700.1	42.9
LArm-F	5c	4205	5200	4641	4700	402.4	8.7
Sweeny	7	2250	2948	2774	2840	240.0	8.7
Reserv	7a	2000	3710	2325	2080	616.2	26.5
Reserv	6b	2000	2240	2090	2080	89.5	4.3
Sarpy	7a	904	3090	2339	2460	794.9	34.0
Sarpy	6c	1770	3090	2578	2650	529.9	20.4
PR-Mo	1	--	--	2200	--	--	--
PR-Mz	1	--	--	2243	--	--	--

*Defined as (100)·(s/mean). a--Calculations were made on all the readings. b--Calculations were made without the unusually high maximum. c--Calculations were made without the unusually low minimum.

equal 2401 umhos which is closely equivalent to McKee and Wolf's (1963) salinity reference criteria for potential instream biotic effects. In addition, if the study area streams should prove to have a viable mixed biota, then many of these waters would fall, on the basis of their salinity levels, into the upper 5% category that was defined by Hart, et al (1945). The close similarity of the man and median salinity values for the project region indicates that the SC readings from the inventory water samples had a fairly equal distribution above and below the central point of the data array. But since the mean/median ratio was slightly above unity (1.01), a few exceptionally high SC values such as the 11,000 collection tended to weight the overall project area mean to the higher end of the data set to a slight degree. The obtainment of biological data in conjunction with these higher salinity levels is of value from a research standpoint by affording a comparative position from which to assess the effects of salinity on the macroinvertebrate associations.

Sampling Site Aspects

The mean and median summary statistics were also quite similar on a station basis with the mean/median SC ratios closely equal to one and in the 0.97 to 1.03 range for 78% of the sampling sites. In all cases, the unity of the ratio was enhanced following the elimination of a uniquely high maximum value or a uniquely low minimum value from the determinations as shown in Table 6. The near unity of these station ratios also denotes a generally equal distribution of SC readings around a central point, although many of the stations (46%) had ratios slightly less than one which indicates the collection of a few samples with comparatively low salinity levels. These low salinity samples were probably collected during a relatively high flow period in the spring and early summer or during a storm event when the higher runoff flows would act to dilute the baseline salinity factor of a stream to some extent. This aspect was most distinct at the TR-ShD and the LRsb-R sites which provided relatively low May to early July SC readings and mean/median ratios of 0.90 and 0.96 respectively.

On the other hand, a few of the individual sites (15%), like the study area as a whole, provided mean/median SC ratios greater than 1.00 which indicate the collection of a few samples at these locations with uniquely high salinity levels. The Pumpkin Creek station was most distinct in this regard with high SC's between 4600 and 800 umhos and with a ratio of 1.56, while the UHWC-D site with its 11,000 reading and the Reserv and EFArm sites had ratios of 1.12, 1.12, and 1.09 respectively. The collection of such extremely high salinity values on a few occasions was adequate to slightly skew the overall SC mean of the study area to the more saline side as was noted earlier.

Most of the inventory sampling sites demonstrated a surprisingly high constancy in the SC variable with percent deviations well below 50%. A part of this reduced variability could be due to a sampling bias that was built into the project wherein a large fraction of the samples were obtained during the warm weather season when stream flows happened to be relatively stable and when fairly constant salinity concentrations might be expected from the streams' baseline flow component. But as a further factor, many of the project region creeks, such as EFHWC, Cow-O, and

Canyon that exhibited markedly low percent deviations at less than 10%, have fairly small drainage areas, and dilutions from runoff inputs, thereby, would be a less significant factor in these cases with the groundwater inputs providing for fairly constant salinity levels. All of the waters with such low percent deviations also had their mean median ratios near unity.

In the case of those streams like the Tongue River that had somewhat high percent deviations above 10% and in the vicinity of 30%, runoff from their larger drainage areas would have a greater dilution effect, and the collection of water samples during a runoff period would produce lower SC values and enhance the SC variability of the station. Mean/median ratios less than one would be obtained in these instances. In contrast, sampling during extremely low flow periods or at uniquely saline locations was stressed in those streams like Youngs and Davis that had high percent deviations and high mean/median ratios greater than one.

Pumpkin and Mizpah Creeks provide the extreme project area examples of a high variability in sample SC concentrations. These streams are characterized by their small but relatively saline baseline flows, by their large drainage areas, and by a large runoff component in response to snowmelt and storm events. Because of these features, wide ranges of SC values were collected from the two creeks as a result of sampling at different hydrological periods, and this produced the high percent deviations that are listed in Table 6 for these waters. Furthermore, Pumpkin and Mizpah Creeks demonstrated extremely broad eighteen-fold and four-fold differences in the minimum and maximum salinity concentrations of their water samples, and these maximum-minimum differences equalled 250% and 120% of their SC means respectively. In contrast, most of the other streams with their lower percent SC deviations revealed much lower 1.1-fold to 1.8-fold maximum-minimum differences which varied between 6% and 63% of their SC means, providing an average of 25% for these particular sites. The other major exception to a relatively narrow salinity range of this kind was found in the 2.7- and 3.8-fold SC differences of the two Tongue River sites; the range/mean factor in these two cases was observed to be in the vicinity of 100% for this mainstem stream.

Assessment Implications and Reference Criteria Descriptions

One of the main objectives of the coalfield area project was to assess the possible effects of salinity on the benthic biota of the study region streams, including the macroinvertebrate component, and to accomplish this objective, one requirement of the sampling program was to collect biological samples under a broad regime of salinity levels. This sampling approach was judged to be essential if salinity effects were to be actually shown in the study data, and it served another project objective by providing information for a wide variety of waters in the project region. As suggested in Table 6, this sampling requirement was ultimately fulfilled through the field efforts of the inventory.

As a point of further significance in this regard, if the mean or median station SC values in Table 6 are ranked from the highest concentration (a rank of one) to the lowest concentration (a rank of 42), this series shows a consistent and gradual decrease in salinities from the lower to the higher ranks

without any major gaps in salinity levels. A distinctly linear relationship is obtained from a graph of salinity versus station rank (r = 0.98), and the greatest discrepancy between any two ranks only equals about 500 umhos which is equivalent to a small 9.3% fraction of the entire salinity range. The change in salinity per increase in rank is greatest at the upper end of the series between 3000 and 6000 umhos, averaging -293 umhos, while at the lower end (400 to 3000 umhos) this change in salinity averages only -89 umhos for each increase in rank. This consistent gradation of salinity concentrations provides the required data base that can be effectively used in the regression-correlation statistical assessments of the project's biological data.

Of further importance to the salinity assessments is the fact that the project area SC concentrations cut across the various general reference criteria that have been developed for this water quality parameter in relation to the fishery and the aquatic biota in general. That is, salinity concentrations in the southern Fort Union streams were found at levels both well above and well below these general guidelines. For example, 50% of the water samples demonstrated salinity values above the 2000 umho SC criteria described by Ellis, et al (1946) as being important for the maintenance of a good mixed fish fauna. Although the stream fishery will not be considered in this report, this observation is suggestive of some biotic effects. Furthermore, the SC means of 40% of the sampling sites and the SC values of 43% of the water samples collected from the study area demonstrated salinity levels in excess of McKee and Wolf's (1963) recommendation for the freshwater biota, and a greater percentage of the stations and samples had salinity levels above the NTAC (1963) guideline of 1500 mg DS/1 as sodium chloride. On this basis therefore, some salinity effects might be predicted for the project region waters, and such effects would be expected to be reflected in the project's biological data base.

As a preliminary assessment approach, these published guidelines can be used as dividers by which to separate the biotic data into high and low salinity sets for comparative purposes. In this fashion, a researcher should be able to ascertain if any detrimental biological differences might actually exist between the macroinvertebrate associations that are collected under the high and low salinity regimes of the streams as defined by the reference criteria. Macroinvertebrate diversity and abundance will be used as the biotic parameters undergoing these comparisons in this particular study. But as a negative note, Bahls (1980) was unable to recognize any adverse relationships between the floral components of the study area streams and the salinity concentrations of these waters.

Waters in the inventory region with salinity concentrations typically above the 2000 mg/1 McKee and Wolf criteria were most commonly identified in one-half of the Tongue River tributaries and in the small Yellowstone River tributaries. Waters with salinity concentrations below this level were generally found in the other half of the Tongue River tributaries, in the Tongue River mainstem, in the Rosebud Creek drainage, and in the Powder River drainage.

RESULTS AND DISCUSSION--NATURAL SUBSTRATE MACROINVERTEBRATE COLLECTIONS

TAXA ENCOUNTERED

Summary Table Descriptions

Table 7 provides a summary listing of all of the aquatic macroinvertebrate taxa that were collected during the coalfield area stream inventory using the natural substrate Surber techniques and the artificial substrate Hester-Dendy techniques. The common names for some of these groups are also presented as available. In addition, the systematic features and relationships of the organisms are included in the table along with a few miscellaneous notes describing some of their significant habits and characteristics. The systematic and behavioral-morphological information was taken primarily from several general reference sources as follows: Pennak (1978), Merritt and Cummins (1978), Edmondson (1959), and Storer and Usinger (1957), along with Burch (1972) and Klemm (1972), while the nomenclatural aspects were developed from the more specific types of references that are listed in Table 4. These same reference sources also describe various other common higher macroinvertebrate taxa that are typically found in aquatic systems but for which no representatives were obtained from the study area streams under the sampling regime of the inventory. The most distinctive of these uncollected taxa, including the Culicidae (dipteran mosquitoes), Corydalinae (megalopteran hellgrammites), Petaluridae (mountain dragonflies), Pteronarcys (plecopteran salmon flies), Rhyacophilidae (free-ranging caddisflies), and Astacidae (crawdads) as examples, have been tagged and incorporated into Table 7 along with the other macroinvertebrate groups.

In some of the cases, the study identifications of all of the specimens collected for a particular animal group had to be stopped at one of the higher systematic designations above the generic level because of keying difficulties or because of one of the other reasons described previously. In other instances, all of the specimens of a taxa could be keyed to family, or most typically, to genera; however, for some of these listings, a few of the representatives could not be so identified because of their small size, their mutilation, or because of some other factor. For whatever reason, the taxonomic identifications that had to be concluded at one of the higher systematic names have been earmarked as such in Table 7. As a further feature, the collection of the larval, adult, and pupal forms are also indicated in Table 7 for those insect taxa where more than one life stage was obtained from the inventory streams. The larval phase was consistently collected for those insect groups that have not been highlighted by a special designation, and for the non-insect taxa, the adult forms were most generally collected and identified during the project.

Almost all of the macroinvertebrate groups that are listed in Table 7 were retrieved from the natural stream substrates using the Surber sampler. A much smaller assortment of these same taxa were also secured with the artificial substrates, and four of the macroinvertebrate taxa were obtained in relatively low abundances only with the Hester-Dendy samplers to the exclusion of the Surber apparatus. In contrast, a large number of the taxa in Table 7 were found only in the natural substrate collections and were not identified as a part of the artificial substrate work. The four unique

Table 7. Taxa list, associated systematics, and selected habits and characteristics of benthic macroinvertebrates collected from streams draining the southern Fort Union region of southeastern Montana (the first page of nine pages).

<u>Phylum</u>: Arthropoda--joint-footed animals
<u>Subphylum</u>: Mandibulata (Antennata)--antennae present
<u>Class</u>: Insecta (Hexapoda)--insects
  <u>Order</u>: Coleoptera (COL)--beetles and weevils
    <u>Family</u>: Carabidae (L)*--predaceous ground beetles
    <u>Family</u>: Chrysomelidae--leaf beetles
      <u>Donacia</u> (L)--clinging beetles
    <u>Family</u>: Curculionidae (L)*--weevils
      <u>Hyperodes</u> (L)--climbing and clinging weevils
      <u>Listronotus</u> (L,A)--climbing and clinging weevils
    <u>Family</u>: Dryopidae--riffle beetles
      <u>Helichus</u> sp. (A)--clinging beetles
      <u>Helichus</u> <u>striatus</u> (A)
    <u>Family</u>: Dytiscidae (L)*--predaceous diving beetles
      <u>Agabus</u> (L,A)--swimming and diving beetles
      <u>Deronectes</u> sp. (A)--swimming and climbing beetles
      <u>Deronectes</u> <u>liodessus</u> (A)
      <u>Deronectes-Oreodytes</u> complex (A)
      <u>Oreodytes</u> (L)--swimming and climbing beetles
      <u>Hydroporus-Hygrotus</u> complex (L)--diving beetles
      <u>Rhantus</u> (L)--swimming and diving beetles
    <u>Family</u>: Elmidae (L)*--riffle beetles
      <u>Dubiraphia</u> sp. (L,A)--clinging and climbing beetles
      <u>Dubiraphia</u> <u>vittata</u> (A)
      <u>Microcylloepus</u> sp. (L,A)--clinging and climbing beetles
      <u>Microcylloepus</u> <u>pusillus</u> (A)
      <u>Optioservus</u> sp. (L,A)--clinging beetles
      <u>Optioservus</u> <u>divergens</u> (A)
      <u>Optioservus</u> <u>quadrimaculatus</u> (A)
      <u>Stenelmis</u> sp. (L,A)--clinging beetles
      <u>Stenelmis</u> sinuata (A)
      <u>Stenelmis</u> <u>sinuata-humerosa</u> complex (A)
      <u>Stenelmis</u> <u>vittipennis</u> (A)
      <u>Zaitzevia</u> <u>parvula</u> (A)--clinging beetles
    <u>Family</u>: Haliplidae--crawling water beetles
      <u>Haliplus</u> (L,A)
    <u>Family</u>: Heteroceridae (L)*--subaquatic and littoral beetles

*An asterisk denotes the collection of a higher taxa representative that could not be identified to the generic level.

L,A: These designations denote the larval and adult forms respectively.

Table 7. Continued (the second page of nine pages).

<u>Class</u>: Insecta--(continued)
    <u>Order</u>: Coleoptera (COL)--(continued)
        <u>Family</u>: Hydrophilidae (L)*--water scavenger beetles
            <u>Berosus</u> (L)--swimming and diving beetles
            <u>Enochrus</u> (L)--burrowing and sprawling beetles
            <u>Helophorus</u> (A)--climbing beetles
            <u>Hydrochus</u> (L)--climbing beetles
            <u>Laccobius</u> (L,A)--swimming and climbing beetles
        Family: Hydraenidae (Limnebiidae)(L)*--crawling water beetles
            <u>Ochthebius</u> (L,A)
        <u>Family</u>: Gyrinidae--whirligig beetles
            <u>Gyrinis</u>-<u>Gyretes</u> complex(L)--surface swimming beetles
        <u>Family</u>: Limnichidae (L)*--riffle beetles
        <u>Family</u>: Noteridae#--burrowing water beetles
    <u>Order</u>: Diptera (DIP)--true flies
    <u>Suborder</u>: Brachycera*
        <u>Family</u>: Dolichopodidae*--burrowing aquatic flies
        <u>Family</u>: Empididae*--dance flies
            <u>Clinocera</u>--clinging flies
            <u>Clinocera</u>-<u>Chelifera</u> complex
            <u>Hemerodromia</u>--sprawling and burrowing flies
        <u>Family</u>: Stratiomyidae*--soldier flies
            <u>Euparyphus</u>--sprawling flies
            <u>Nemotelus</u>--swimming and sprawling flies
            <u>Odontomyia</u> (<u>Eulalia</u>)--sprawling flies
            <u>Stratiomys</u> (<u>Stratiomyia</u>)--sprawling and burrowing flies
        <u>Family</u>: Tabanidae*--horse and deer flies
            <u>Chrysops</u>--sprawling and burrowing flies
            <u>Tabanus</u>--sprawling and burrowing flies
    <u>Suborder</u>: Cyclorrhapha
        <u>Family</u>: Ephydridae--shore and brine flies
            <u>Hydrellia</u>--burrowing and mining flies
        <u>Family</u>: Muscidae (Anthomyiidae)*--aquatic houseflies
            <u>Limnophora</u>--burrowing flies
        <u>Family</u>: Scatophagidae*--dung flies

*An asterisk denotes the collection of a higher taxa representative that could not be identified to the generic level.

L,A: These designations denote the larval and adult forms respectively.

#This designation denotes a generally lotic and/or relatively common higher taxa for which no representatives were collected from the study area streams.

Table 7. Continued (the third page of nine pages).

Class: Insecta--(continued)
- Order: Diptera (DIP)--(continued)
- Suborder: Nematocera
  - Family: Blephariceridae#--net-winged midges
  - Family: Ceratopogonidae (Heleidae)*--biting midges,"no-see-ums"
    - Bezzia--burrowing midges
    - Bezzia-Probezzia complex
    - Bezzia-Probezzia-Palpomyia complex
    - Palpomyia--burrowing midges
    - Culicoides--burrowing midges
  - Family: Chironomidae*--true midges
  - Family: Culicidae#--mosquitoes
  - Family: Deuterophlebiidae#--mountain midges
  - Family: Dixidae--dixid or dixa midges
    - Dixa--swimming and climbing midges
  - Family: Psychodidae*--moth flies
    - Pericoma--burrowing flies
  - Family: Ptychopteridae#--phantom crane flies
  - Family: Simuliidae--black flies
    - Simulium (L,P)--clinging flies
  - Family: Tipulidae*--crane flies
    - Dicranota--sprawling and burrowing flies
    - Ormosia--semiaquatic, burrowing flies
    - Pseudolimnophilia--burrowing flies
    - Tipula--burrowing flies
- Order: Ephemeroptera (EPH)*--mayflies
  - Family: Baetidae*
    - Baetis--rapid water, free-ranging mayflies
    - Pseudocloeon--swimming and clinging mayflies
  - Family: Baetiscidae#--sprawling and clinging mayflies
  - Family: Caenidae
    - Caenis--quiet water, bottom sprawling mayflies
  - Family: Ephemerellidae*
    - Ephemerella--variable mayflies
  - Family: Ephemeridae
    - Ephemera--quiet water, burrowing mayflies

*An asterisk denotes the collection of a higher taxa representative that could not be identified to the generic level.

L,P: These designations denote the larval and pupal forms respectively.

#This designation denotes a generally lotic and/or relatively common higher taxa for which no representatives were collected from the study area streams.

Table 7. Continued (the fourth page of nine pages).

Class: Insecta--(continued)
Order: Ephemeroptera (EPH)*--(continued)
Family: Heptageniidae*
Heptagenia--running water, clinging mayflies
Rhithrogena--running water, clinging mayflies
Stenonema--running water, clinging mayflies
Family: Leptophlebiidae*
Choroterpes--clinging and bottom sprawling mayflies
Choroterpes-Leptophlebia complex
Leptophlebia--clinging and swimming mayflies
Paraleptophlebia--rapid water, free-ranging mayflies
Family: Polymitarcyidae
Ephoron--quiet water, burrowing mayflies
Family: Siphlonuridae
Ameletus--rapid water, free-ranging mayflies
Siphlonurus--quiet water, climbing mayflies
Family: Tricorythidae
Tricorythodes--clinging, bottom-sprawling mayflies
Order: Hemiptera (HEM)--true bugs
Suborder: Heteroptera (L,A)*--aquatic bugs
Family: Corixidae (L,A)*--water boatmen
Hesperocorixa sp. (A)--swimming and climbing bugs
Hesperocorixa laevigata (A)
Hesperocorixa vulgaris (A)
Sigara sp. (A)--swimming and climbing bugs
Sigara comani (A)
Sigara trillineata (A)
Trichocorixa (L,A)--swimming and climbing bugs
Family: Gerridae--water striders, pond skaters, wherrymen
Gerris sp. (A)--skating bugs
Gerris remigis (A)
Family: Naucoridae--creeping water bugs
Ambrysus mormon (A)
Family: Notonectidae#--back swimmers
Family: Saldidae (A)*--shore bugs
Family: Veliidae#--broad-shouldered water striders
Suborder: Homoptera (L)*--cicadas, aphids, etc., semiaquatic bugs

*An asterisk denotes the collection of a higher taxa representative that could not be identified to the generic level.

L,A: These designations denote the larval and adult forms respectively.

#This designation denotes a generally lotic and/or relatively common higher taxa for which no representatives were collected from the study area streams.

Table 7. Continued (the fifth page of nine pages).

Class: Insecta--(continued)
- Order: Lepidoptera (LEP)--butterflies and moths
  - Family: Pyralidae--aquatic caterpillars
    - Parargyractis--silk retreat makers
- Order: Megaloptera (MEG)--alderflies, dobsonflies, and fishflies
  - Family: Sialidae*--alderflies
    - Sialis--burrowing, climbing, and clinging alderflies
  - Family: Corydalidae
  - Subfamily: Corydalinae#--dobsonflies and hellgrammites
  - Subfamily: Chauliodinae--fishflies
    - Dysmicohermes--clinging and climbing fishflies
- Order: Odonata (ODO)*--dragonflies and damselflies
- Suborder: Anisoptera (ANI)*--true dragonflies
  - Family: Aeshnidae--darners
    - Aeshna--climbing dragonflies
  - Family: Gomphidae*
    - Gomphus--burrowing dragonflies
    - Ophiogomphus--burrowing dragonflies
  - Family: Libellulidae*
    - Leucorrhinia--climbing dragonflies
  - Family: Petaluridae#--mountain dragonflies
- Suborder: Zygoptera (ZYG)*--damselflies
  - Family: Calopterygidae (Agriidae)
    - Hetaerina sp.--climbing and clinging damselflies
    - Hetaerina americana
  - Family: Coenagrionidae (Coenagriidae)*
    - Argia sp.--clinging and climbing-sprawling damselflies
    - Argia (Hyponedra) vivida
    - Ischnura--climbing damselflies
- Order: Plecoptera (PLE)--stoneflies
  - Family: Chloroperlidae*--clinging stoneflies
  - Family: Nemouridae*
    - Nemoura(a)--sprawling and clinging stoneflies
  - Family: Perlidae
    - Acroneuria(a)--clinging stoneflies
  - Family: Perlodidae*
    - Isogenus(a)--clinging stoneflies
    - Isoperla--clinging and sprawling stoneflies
  - Family: Pteronarcyidae#--clinging and sprawling stoneflies
    - Pteronarcys#--salmon flies ("hellgrammites")

*An asterisk denotes the collection of a higher taxa representative that could not be identified to the generic level.

(a)These stonefly genera have numerous subgenera which are often given a generic rank by some authorities.

#This designation denotes a generally lotic and/or relatively common higher taxa for which no representatives were collected from the study area streams.

Table 7. Continued (the sixth page of nine pages).

Class: Insecta--(continued)
Order: Trichoptera (TRI)--caddisflies
Family: Brachycentridae*--tapered tube-case makers
Brachycentrus--clinging caddisflies
Family: Glossosomatidae*--saddle-case,turtle shell-case makers
Culoptila--clinging caddisflies
Family: Helicopsychidae--snail shell-like, tube-case makers
Helicopsyche--clinging caddisflies
Family: Hydropsychidae*--net-spinning, fixed retreat makers
Cheumatopsyche--clinging caddisflies
Hydropsyche--clinging caddisflies
Potamyia--clinging caddisflies
Family: Hydroptilidae (L,P)*--purse-case, microcaddisflies
Hydroptila (L,P)--silken case, clinging caddisflies
Ithytrichia (L,P)--silken case, clinging caddisflies
Ochrotrichia--silken case, clinging caddisflies
Family: Lepidostomatidae#--climbing, sprawling tube-case makers
Family: Leptoceridae (L,P)*--variable tube-case make
Nectopsyche (*Leptocella*)--climbing, swimming caddisflies with long and slender tube-cases
Oecetis--clinging,sprawling caddisflies with curved and tapered tube-cases
Family: Limnephilidae*--variable tube-case makers
Anabolia--climbing and sprawling caddisflies with rough tube-cases of plant pieces
Glyphopsyche--sprawling caddisflies with smooth tube-cases of plant pieces
Hesperophylax (*Platyphylax*)(L,P)--sprawling caddisflies with slightly curved and slightly coarse mineral tube-cases
Limnephilus--climbing and sprawling caddisflies with variable tube-cases of plant pieces and/or sand grain construction
Onocosmoecus--sprawling caddisflies with tube-cases of plant pieces or minerals
Psychoglypha--sprawling and clinging caddisflies with mixed tube-cases of plant pieces and minerals

*An asterisk denotes the collection of a higher taxa representative that could not be identified to the generic level.

L,P: These designations denote the larval and pupal forms respectively.

#This designation denotes a generally lotic and/or relatively common higher taxa for which no representatives were collected from the study area streams.

Table 7. Continued (the seventh page of nine pages).

Class: Insecta--(continued)
Order: Trichoptera (TRI)--(continued)
Family: Odontoceridae#--sprawling tube-case makers
Family: Philopotamidae#--clinging, sack-like net spinners
Family: Phryganeidae--cylindrical tube-case makers
Ptilostomis--climbing caddisflies
Family: Polycentropodidae--net-spinning retreat makers
Neureclipsis--clinging caddisflies with trumpet-shaped silk nets
Nyctiophylax--clinging caddisflies with silk tube retreats
Polycentropus--clinging caddisflies with silk tube retreats
Family: Rhyacophilidae#--free-living, free-ranging, and clinging caddisflies having no cases

Phylum: Arthropoda--joint-footed animals
Subphylum: Mandibulata (Antennata)--antennae present
Class: Crustacea--crustaceans
Subclass: Ostracoda (OST)*--seed shrimp
Order: Podacopa*--freshwater seed shrimp
Subclass: Malacostraca--lobsters, crabs, sow bugs, scuds, crayfishes, etc.
Order: Isopoda#--aquatic sow bugs
Order: Amphipoda (AMP)--scuds, sideswimmers, "freshwater shrimp"
Family: Gammaridae
Gammarus
Family: Talitridae--common sideswimmer
Hyalella azteca--only Talitridae in North America
Order: Decapoda#--lobsters, crabs, crayfishes, etc.
Family: Astacidae#--crayfishes, crawfishes, crawdads

Phylum: Arthropoda--joint-footed animals
Subphylum: Chelicerata--antennae absent
Class: Arachnida (Arachnoidea)--spiders, scorpions, mites, ticks, etc.
Order: Acari (Acarina) (ACA)*--mites and ticks
Group: Hydracarina (Hydrachnellae) (b)*--water mites

*An asterisk denotes the collection of a higher taxa representative that could not be identified to the generic level.

#This designation denotes a generally lotic and/or relatively common higher taxa for which no representatives were collected from the study area streams.

(b) The Hydracarina is an artificial assemblage of several families in the acarian suborder Trombidiformes that are restricted to freshwater habitats along with certain of the Sarcoptiformes and the Parasitiformes which also have an aquatic habit.

Table 7. Continued (the eighth page of nine pages).

Phylum: Annelida--segmented worms
Class: Hirudinea (HIR)*--leeches
    Order: Gnathodellida--no protrusible proboscis, five eye pairs
        Family: Hirudinidae
            Percymoorensis marmoratis
    Order: Pharyngobdellida--no protrusible proboscis, three or four eye pairs
        Family: Erpobdellidae*
            Dina anoculata
            Erpobdella
    Order: Rhynchobdellida--protrusible proboscis present
        Family: Glossiphoniidae*
            Batracobdella
            Glossiphonia sp.
            Glossiphonia complanata
            Helobdella sp.
            Helobdella stagnalis
            Placobdella sp.
            Placobdella papillifera
            Theromyzon#
        Family: Piscicolidae#
Class: Oligochaeta (OLI)*--aquatic earthworms

Phylum: Mollusca--molluscs
Class: Gastropoda (GAS)*--snails and periwinkles (univalve molluscs)
Subclass: Prosobranchia#--possess a gill and operculum
    Order: Mesogastropoda#--mostly marine species
Subclass: Pulmonata--possess a pulmonary sac (lung) and lack an operculum
    Order: Basommatophora--freshwater snails
        Family: Ancylidae--cone snails
            Ferrisia
        Family: Lymnaeidae--pond snails
            Lymnaea
        Family: Planorbidae--orb snails
            Gyraulus
            Helisoma
        Family: Physidae*--pouch snails
            Physa
        Family: Pupillidae
            Columnella

*An asterisk denotes the collection of a higher taxa representative that could not be identified to the generic level.

#This designation denotes a generally lotic and/or relatively common higher taxa for which no representatives were collected from the study area streams.

Table 7. Continued (the ninth page of nine pages).

Phylum: Mollusca--(continued)
Class: Pelecypoda (PEL)*--clams and mussels (bivalve molluscs)
    Order: Eulamellibranchia
        Family: Unionidae*--pearly mussels or naiads
    Order: Heterodonta
        Family: Sphaeriidae--pea, pill, and fingernail clams
            Pisidium--anterior of shell longer than posterior
            Sphaerium--posterior of shell longer than anterior

Phylum: Platyhelminthes--flatworms
Class: Turbellaria (TUR)*--free-living flatworms

Phylum: Aschelminthes--roundworms
Class: Nematoda (NEM) (c)*--nematodes
Class: Nematomorpha (NMT) (c)*--hair snakes or horsehair worms
    Order: Gordiida (Gordioidea)*--gordian worms

*An asterisk denotes the collection of a higher taxa representative that could not be identified to the generic level.

(c)The Nematoda and the Nematomorpha are each given a phylum rather than a class ranking by some authorities.

taxa that were found only in the Hester-Dendy samples can be listed as follows: Chloroperlidae, a plecopteran (stonefly) family; Clinocera (Empididae), a dipteran genus (dance fly) in the suborder Brachycera; and Anabolia (Limnephilidae) and Nyctiophylax (Polycentropodidae) which are trichopteran (caddisfly) genera. These taxa should be excluded from any considerations of the natural substrate work. In addition, Hesperocorixa vulgaris (Corixidae), a hemipteran-heteropteran (true aquatic bug) representative, and Placobdella papillifera, a hirudinid (leech) specimen, could be keyed to species only in the artificial substrate collections, although these same two genera were also spotted in some of the Surber samples.

Taxa Numbers

As illustrated in Table 7, eleven classes and subclasses of aquatic macroinvertebrate organisms, involving five phyla as defined by Storer and Usinger (1957) (Annelida, Aschelminthes, Arthropoda, Mollusca, and Platyhelminthes), were identified in the many biotic collections obtained during the course of the project. Of these classes and subclasses, five (Ostracoda, Oligochaeta, Turbellaria, Nematoda, and Nematomorpha) could not be keyed to lower systematic levels given the design and taxonomic requirements of the study. Of the other six classes-subclasses, three (Hirudinea, Gastropoda, and Pelecypoda) provided a few specimens that could not be further identified, although all of the representatives from the remaining classes-subclasses (Insecta, Malacostraca, and Arachnida), all arthropods, were consistently taken to a lower systematic category. These six classes-subclasses produced 21 orders and suborders of macroinvertebrates. Two of the orders-suborders (Acari-Hydracarina and Hemiptera-Homoptera) could not be identified to the family level, and four of these(Diptera-Brachycera, Ephemeroptera, Odonata-Anisoptera, and Odonata-Zygoptera) included a few specimens that could not be keyed to the subsequent systematic group. However, representatives for fifteen of these orders-suborders (e.g., Coleoptera, Plecoptera, Trichoptera, and Amphipoda) were always tagged with a family name.

The nineteen macroinvertebrate orders that could be systematically carried to the next category involved the identification of 71 distinct families, and representatives for nine of these families (e.g., Chloroperlidae, Carabidae, and Unionidae) could not be identified to the generic level. Of the other 62 families, one-half produced a few individuals that could not be keyed to genus while the other one-half had specimens that could always be labelled with a generic name. These 62 families provided 118 to 122 macroinvertebrate genera, and of these genera, 23 to 24 could be keyed to a species epithet. The discrepancies in the total number of generic and specific identifications are due to the collection of five macroinvertebrate types that could only be taken to a two- or three-name nomenclatural complex because of keying difficulties. One example is the Clinocera-Chelifera complex in the dipteran order. In these cases, at least one of the generic or specific names in a couplet or triplet had not been identified in the inventory samples as a separate and definite macroinvertebrate entity. As a result, the existence of this organism in the study area is not definitely known. Continuing with this same example, Chelifera was not recognized from the study area streams as a discrete specimen, although Clinocera was identified in this way.

Thus Chelifera might be present in the project region, but since this has not been confirmed, the Clinocera-Chelifera complex could be representative of either one or two taxa.

Species recognitions could be made with nine to ten of the coleopteran forms (beetles), with six of the heteropteran genera, with two of the zygopteran genera (damselflies), and with five of the hirudinid genera which involved the three orders of this latter macroinvertebrate class. Of these identifications, however, eighteen to nineteen produced some individuals of the same genera that could not be taken to species. But five of the organisms, Zaitzevia parvula (Coleoptera), Ambrysus mormon (Heteroptera), Hyalella azteca (Amphipoda), Percymoorensis marmoratis (Hirudinea), and Dina anoculata (Hirudinea), were keyed to a specific epithet on a consistent basis because of the excellent specimens and/or because of their unique characteristics.

The previous discussion indicates that 134 to 139 discrete macroinvertebrate taxa were recognized for the project area waters within the taxonomic limits that were imposed upon the inventory. These taxa were identified as 23 to 24 genus-species, as 95 to 99 genera, as nine families, as two orders-suborders, and as five classes-subclasses. However, since the laboratory work demonstrated less than a 100% taxonomic resolution, this total count probably underestimates by a considerable margin the actual number of taxa that were collected during the course of the study. On the one hand, the keying efforts of a macroinvertebrate assemblage that had to be concluded at the family level or at some higher systematic category, resulting in the tabulation of only one taxa, probably involved the occurrence of several lower level taxa if more complete identifications could have been made on all of the specimens. The recognition of these lower taxonomic series in turn would have acted to enhance the total taxa count.

The most obvious example of a discrepancy of this kind in this study is found with the dipteran Chironomidae family (true midges) which was counted as one taxa but which includes about 140 genera and on the order of 2,500 unique species for the North American continent (Merritt and Cummings, 1978). With the collection of an average of 270 chironimid individuals per square foot of stream bottom in the coalfield investigation (Klarich, et al, 1980), several midge species would be expected for each of the study's biotic samples, especially in view of the fact that 50 species of this group are typically observed in most freshwater systems. The generic and specific identifications of these midges would have greatly increased the total taxa count of the study, and similar results might be anticipated for the oligochaetes, the turbellarians, and the other ambiguous forms. That is, more than one type of aquatic earthworm, flatworm, and other nondistinctive animals would be expected for the study region, although only one taxa at the family through class level could be recorded for each of these particular macroinvertebrate groups.

Furthermore, some of the identifications at the generic level could have involved more than one species as illustrated by certain of the coleopterans, and the recognition of additional multispecies genera for the project also would have resulted in an elevation of the total taxa numbers. One example of the likelihood of such an occurrence in this study was found in several of the inventory collections where two or three possible species of Cheumatopsyche and/or Hydropsyche (trichopterans) were spotted

in the samples on the basis of minor marphological differences between different sets of the organisms. However, keys were not available by which to confirm the actual existence of the separate species or by which to label the different organisms with an accepted species name. This same situation could hold true for many of the other macroinvertebrate genera that were collected in a larval stage, and as a result, more than 139 taxa were probably obtained from the streams. If the 50% resolution factor described previously is a fairly accurate estimate of the taxonomic prowess of the inventory, then 270 total taxa would be expected for the region in the case where complete systematic identifications could have been made on all of the organisms.

The dipteran, coleopteran, and trichopteran insect orders made the greatest contribution to the faunal richness of the project region streams. This is prbably due to the generally large number of genera in these groups and to the benthic nature of many the orders' organisms. These three orders provided 54.7% of the discrete taxa that were encountered and identified during the taxonomic work (21.6%, 18.0%, and 15.1% respectively). The ephemeropterans and hemipterans contributed an additional 10.8% and 5.8% respectively, and the other insect orders accounted for 11.5% of the taxa. The remaining contributions can be summarized as follows: Hirudinea--5.0%, Gastropoda--4.3%, Pelecypoda--2.2%, and Amphipoda--1.4%, while the broader class groupings (Acari, Oligochaeta, Ostracoda, Nematoda, Nematomorpha, and Turbellaria) represent 4.3%. Since the insects accounted for 82.8% of the taxa collected during the project, these particular organisms appear to be the most significant faunal diversity factors in the coalfield aquatic systems. In addition, the insects are probably the most important benthic animals in these waters in an ecological sense.

General Taxa Characteristics

Habits and Habitats. As indicated by the descriptions in Table 7, most of the macroinvertebrates collected during the study have a truly benthic life-style as described by their clinging, sprawling, and burrowing-mining characteristics. Obvious examples of these benthic organisms are the riffle beetles, many of the dipterans, almost all of the trichopterans, some of the emphemeropterans (mayflies), and most of molluscs (snails and mussels). This type of faunal dominance might be expected for the inventory in view of the collection techniques that were used to retrieve the samples. However, some of the organisms that were obtained by the Surber sampler had features that would be best described as largely atypical for a benthic stream habitat. Such non-benthic macroinvertebrates were probably occasionally collected as temporary migrants to the stream bottom, or they were inadvertently trapped during the sampling process.

These benthic visitors can be generally characterized by their swimming and diving activities, and the best examples of these organisms are the Dytiscidae (predaceous diving beetles), the Gyrinidae (whirligig, surface swimming beetles), the hemipteran-heteropteran Gerridae (water striders and pond skaters), and the heteropteran Corixidae (swimming and climbing bugs). Furthermore, organisms that demonstrate a penchant for climbing might also be viewed as primarily non-benthic in nature. The water scavenger beetles (Hydrophilidae), the dipteran dixid midges

(Dixidae-Dixa), some of the anisopteran dragonflies (e.g., Aeshnidae-Aeshna), and at least one of the zygopteran damselflies (Coenagrionidae-Ischnura) are known for their climbing habits. In addition, the Carabidae (predaceous ground beetles), the Heteroceridae (littoral beetles), the Scatophagidae (dung flies), the Saldidae (shore bugs), and the Homoptera (semiaquatic bugs) represent somewhat unique specimens for collection from a stream bottom. But in all cases, the generally non-benthic macroinvertebrates that are summarized by these latter listings were collected in relatively small quantities from the study region streams in contrast to the faunal dominance of the truly benthic forms in the inventory samples.

Trophic Relationships. For the most part, all of the trophic relationships or food habits that might be expected from an assortment of benthic animals are expressed by the many types of macroinvertebrates that have been observed in the project's biotic collections (Table 7). The trophic requirements of most of these animals have been described by Merritt and Cummings (1978) and by Pennak (1978).

At the herbivorous end of the spectrum are the grazers or scrapers that utilize the periphyton, i.e., microalgae such as diatoms, and the other materials (detritus and microorganisms) that are found attached to or associated with the submerged objects of a stream. Many examples of the insect grazers or scrapers have been identified in the inventory samples such as Parargyractis (lepidopteran), some of the dipteran soldier flies or Stratiomyidae (Euparyphus and Odontomyia), and the riffle beetles (Elmidae and Dryopidae). A large number of the Ephemeroptera (e.g., Baetidae, Heptageniidae, and Leptophlebiidae) and some of the Trichoptera (e.g., Glossosomatidae) also fall into this trophic category, although there are numerous exceptions to this feeding approach in these two groups of animals; exceptions include the predaceous species of Siphlonurus (ephemeropterans) and the generally predaceous Polycentropodidae (trichopterans). In addition, the non-insect gastropods (snails) generally act as scrapers in a stream and utilize attached algal materials. However, Physa and Lymnaea are also somewhat omnivorous in character by consuming dead plant and animal tissues on occasion to supplement their grazing activities. Thus some of the snails play a scavenging or cleaning role in an aquatic system.

A second type of herbivore encountered in the study samples have a browsing or shredding nature and use living or dead vascular plant material and coarse particulate organic matter as a source of food. Some of these shredding organisms are characterized by their chewing proclivities, e.g., leaf beetles (Chrysomelidae), weevils (coleopteran Curculionidae), and the Limnephilidae (trichopterans), and a few actually mine the macrophytic tissue. Another of the herbivores along this same line pierces the plants (e.g., the coleopteran Haliplus and hemipteran Sigara) to obtain the cellular fluids, and some of the grazers can use the filamentous macroalgae for food as well as the higher plants. Nemoura, a plecopteran genus, provides a further example of a shredder, although most of the stonefly larvae are carnivorous in habit. Organisms like Nemoura that can utilize dead plant tissues and/or coarse organic matter are often classified as detrivores, and along with some of the snails, these animals also function as scavengers in a stream. The amphipods (scuds and sideswimmers), in turn, act as omnivorous scavengers by feeding on both dead plant and animal materials.

In addition, a few of the turbellarians (flatworms), Acari (aquatic mites), Pharyngobdellidae (leeches), Gerridae, and Saldidae can assume a scavenging role in certain situations.

Many of the shredders and scrapers have a secondary trophic function by consuming decomposing fine particulate organic matter along with the larger plant materials, and many of the trichopterans follow this mode of existence. Furthermore, a number of macroinvertebrates have to depend entirely on the first activity as a means of securing their sustenance, and these kinds of organisms are generally termed the collectors of an aquatic ecosystem. Such collectors can be further split into two broad groups: the gatherers or deposit-sediment feeders and the filterers or suspension feeders. Examples of the gatherers that were identified during the study are the adult Hydrophilidae and the Limnichidae (coleopterans), the dipteran Psychodidae and Ormosia, and the ephemeropteran Tricorythidae and Polymitarcyidae. The aquatic oligochaetes (worms), which ingest food much like their terrestial counterparts, might also be placed into this same grouping. Examples of the filterers are some of the dipteran Chironomidae (midges), the Simulium (black flies), and some of the Trichoptera (e.g., Hydropsychidae). In addition, members of the Pelecypoda (clams and mussels) would be relegated to this filtering category. All of these collecting organisms can also be classified as detrivores.

At the other end of the trophic spectrum from the herbivores are the different macroinvertebrate carnivores which utilize living animal tissues, and a wide variety of carnivorous specimens were collected during the study. One group of carnivores act as piercers and stab the animal tissues to suck the cellular fluids, while a second category consists of the true predators or engulfers which consume whole animals or major parts thereof. Examples of the piercers are the Dytiscidae (precaceous diving beetles) and some of the hemipterans (Hesperocorixa, Trichorixa, and Ambrysus mormon). Examples of the engulfers can be listed as follows: Coleoptera--Carabidae and the Hydrophilidae larvae; Diptera--Empididae, Muscidae, Ceratopogonidae, and some of the Chironomidae; Megaloptera--Dysmicohermes and Sialis; Plecoptera--Isogenus, Isoperla, and Acroneuria; Anisoptera--Gomphus, Ophiogomphus, and Aeshna; and Zygoptera--Hetaerina, Argia, and Ischnura. As a sidelight, the zygopterans and Aeshna have refined their predatory activities by stalking their prey in contrast to many of the other engulfers which tend to await their prey in a passive fashion.

Non-insect carnivores observed in the study collections are some of the turbellarians which consume small invertebrates, Glossiphonia complanata and Helobdella stagnalis which feed on snails (snail leeches), some of the Pharyngobdellidae (leeches) which prey on small invertebrates, and most of the Acari. A few non-insect specimens having a parasitic habit, which is a specialized form of carivory, were also identified as follows: the gordian worms (Nematomorpha) which are parasitic in their immature stages but free-living later on; Placobdella and some of the Helobdella (leeches) which are temporary parasites on fish, frogs, and turtles; and the Hirudinidae, another type of leech, which are the true bloodsuckers, an activity for which the leeches are primarily known.

About 26% of the discrete macroinvertebrate taxa collected from the southern Fort Union streams can be primarily classified as herbivores

(scrapers and shredders), 34% as carnivores (piercers and engulfers), and 27% as detrivores (collectors, gatherers, filterers, and scavengers). But as noted, some of the organisms have more than one nutritional activity which makes a trophic classification difficult in some of the cases. Also, the trophic relationships for 13% of the taxa are unknown or so highly variable that a particular genera or a higher systematic category could not be definitely assigned to any particular trophic group (e.g., the nematodes and the dipteran Tipula).

The true flies collected during the project were found to be most typically carnivores and detrivores on a 50%:50% basis with only a few herbivores, while the beetles were most commonly identified as carnivores and herbivores on a 50%:50% basis with only a couple of detrivores. The caddisflies (and the lepidopteran) afford another option and were recognized as herbivores and detrivores on a 50%:50% basis with only a very few carnivores. In contrast, the mayflies of the study were found to be primarily detrivores with no definite carnivores and only a few herbivores, while the dragonflies, damselflies, hemipterans, megalopterans, and stoneflies were generally identified as carnivores with only one or two herbivores and no detrivores. Of the non-insect taxa, the leeches and Acari were generally listed as carnivores, the amphipods, oligochaetes, and pelecypods were listed as detrivores, and the snails were listed as herbivores. These different trophic relationships and the various trophic interactions of these many kinds of macroinvertebrate organisms among themselves and with the vertebrates, microinvertebrates, macrophytes, macroalgae, microalgae, and the nonliving and other living materials in the study region streams undoubtedly provide for relatively complex food chains and food webs within these aquatic systems. However, further elucidations of these particular ecological features are beyond the scope of this current report.

ABUNDANCE AND DISTRIBUTION

Minor Taxa

Tabular Considerations. All of the abundance determinations that were made during the inventory are presented in the data report according to sampling station, taxa, and collection date (sample). A review of this density information shows that a fairly large number of the taxa listings were uncovered in relatively small quantities from the study area streams and were identified at only a few of the sampling sites. In order to segregate these kinds of listings from the more dominant and abundant taxa, and for tabulation purposes, a minor taxa category was developed and defined as those macroinvertebrate groups that were recognized at less than four of the sampling sites described in Tables 1 and 2. The mean densities of the taxa that follow this definition, as calculated from the station samples, are listed in Table 8 for each of the locations where a minor taxon was encountered. This table also lists a mean density for each of the minor taxa on a study area basis as averaged across the 35 stations, and these overall means should afford some insight into the general importance of a particular macroinvertebrate with reference to the entire coalfield region and in relation to the more dominant forms.

The macroinvertebrate listings and the related density data in Table 8

Table 8. Mean sampling station abundance-density and study area means (SAM) of minor macroinvertebrate taxa (number of individuals per square meter) collected from natural stream substrates in the southern Fort Union region (the first page of three pages).

Taxa		Stream Station and Density	SAM
COL:	Carabidae*	LHWC-B: 1.1	0.03
	Donacia	LOtr-A: 1.1	0.03
	Curculionidae*	LRsb-R: 21.5; LHWC-B: 1.1; EFHWC: 2.2	0.7
	Hyperodes	MRsb-C: 3.2; UHWC-D: 1.1t	0.1
	Listronotus	Logging: 3.2; UOtr-O: 6.5t	0.3
	Dytiscidae*	Mizpah: 3.2	0.09
	Deronectes sp.	UOtr-O: 6.5	0.2
	Deronectes liodessus	Davis: 3.2; Reserv: 10.8	0.4
	Deronectes-Oreodytes	Davis: 3.2	0.09
	Oreodytes	Reserv: 25.8	0.7
	Hydroporus-Hygrotus	Davis: 3.2t	0.09
	Rhantus	Bear: 3.2t	0.09
	Elmidae*	LHWC-B: 1.1	0.03
	Stenelmis sinuata-humerosa	LOtr-A: 1.1	0.03
	Zaitzevia parvula	TR-ShD: 3.2t	0.09
	Heteroceridae*	Indian: 2.2t; TR-PBB: 2.2	0.1
	Hydrophilidae*	Bear: 7.5	0.2
	Enochrus	Bear: 21.5t	0.6
	Helophorus	Bear: 7.5	0.2
	Hydrochus	URsb-K: 1.1t	0.03
	Laccobius	Bear: 10.8t; LOtr-A: 1.1; Pmpkn: 3.2	0.4
	Hydraeinidae*	LOtr-A: 1.1	0.03
	Ochthebius	Cook: 7.5; Pmpkn: 1.1t	0.2
	Gyrinis-Gyretes	Davis: 3.2t	0.09
	Limnichidae*	Davis: 3.2t	0.09
DIP:	Brachycera*	TR-PBB: 1.1	0.03
	Dolichopodidae*	LHWC-B: 1.1t; EFHWC: 1.1	0.06
	Empididae*	UHWC-D: 3.2; LHWC-B: 17.2	0.6
	Stratiomyidae*	Davis: 3.2; Canyon: p; EFHWC: 1.1	0.1
	Nemotelus	Cook: 7.5t; Cow-O: 5.4; LOtr-A: 1.1	0.4
	Odontomyia	Davis: 3.2	0.09
	Stratiomys	Deer: 10.8; Bear: 3.2	0.4
	Tabanidae*	Reserv: 2.2	0.06
	Hydrellia	Lame Dr: 46.3	1.3
	Scatophagidae*	WFArm: 16.1t	0.5
	Bezzia	UOtr-O: 7.5t	0.2
	Culicoides	Sqrrl: 1.1	0.03
	Dixa	EFHWC: 1.1	0.03
	Psychodidae*	Logging: 7.5	0.2
	Pericoma	Indian: 30.1; Cook: 29.1; EFHWC: 20.4	2.3
	Tipulidae*	Indian: 7.5; Deer: 14.0; WFArm: 5.4t	0.8
	Ormosia	Deer: 143.1	4.1
	Pseudolimnophilia	Logging: 3.2t	0.09

*Denotes the collection of a higher taxa representative that could not be identified to the generic level.

Table 8. Continued (the second page of three pages).

	Taxa	Stream Station and Density	SAM
EPH:	Ephemerellidae*	UHWC-D: 1.1t	0.03
	Ephemerella	TR-ShD: 207.7; TR-PBB: 498.2	20.2
	Ephemera	TR-ShD: 3.2; TR-PBB: 3.2	0.2
	Heptagenia	TR-PBB: 9.7; Mizpah: 1.1t	0.3
	Rithrogena	TR-ShD: 3.2	0.09
	Stenonema	TR-ShD: 3.2; TR-PBB: 12.9	0.5
	Leptophlebia	TR-PBB: 12.9; Pr Dog: 10.8	0.7
	Paraleptophlebia	MRsb-C: 14.0	0.4
	Ephoron	MRsb-C: 3.2; TR-ShD: 5.4	0.2
	Ameletus	Lame Dr: 10.8t	0.3
	Siphlonurus	TR-PBB: 3.2t	0.09
HEM:	Corixidae*	LOtr-A: 1.1; Pmpkn: 1.1	0.06
	Hesperocorixa sp.	Reserv: 2.2	0.06
	Hesperocorixa laevigata	Davis: 67.8	1.9
	Sigara sp.	Pmpkn: 3.2; Mizpah: 1.1	0.1
	Sigara comani	Cook: 57.0	1.6
	Sigara trillineata	UHWC-D: 1.1	0.03
	Trichorixa	Deer: 3.2	0.09
	Gerris sp.	Lame Dr: 8.6	0.2
	Gerris remigis	Pr Dog: 10.8; Cow-O: 5.4	0.5
	Homoptera*	TR-PBB: 2.2	0.06
LEP:	Lepidoptera	------------	--
MEG:	Sialidae*	Logging: 43.0	1.2
	Dysmicohermes	Logging: 3.2	0.09
ODO:	Odonata*	UHWC-D: 1.1; EFHWC: 1.1	0.06
ANI:	Anisoptera*	URsb-K: 1.1	0.03
	Aeshna	Deer: 3.2; Logging: 21.5; Reserv: 2.2	0.8
	Gomphidae*	Sqrrl: p	p
	Gomphus	TR-PBB: 3.2; Sarpy: 5.4	0.2
	Libellulidae*	WFArm: 10.8; Reserv: 2.2	0.4
	Leucorrhinia	Beaver: 8.6	0.2
ZYG:	Zygoptera*	LHWC-B: 1.1	0.03
PLE:	Nemouridae*	Cow-O: 32.3	0.9
	Nemoura	Cow-O: 91.5	2.6
	Acroneuria	TR-PBB: 2.2; PR-Mo: 43.0	1.3
	Perlodidae*	URsb-K: 1.1; Ash: 14.0; TR-PBB: 500.3	14.7
	Isogenus	URsb-K: 4.3t	0.1

*Denotes the collection of a higher taxa representative that could not be identified to the generic level.

Table 8. Continued (the third page of three pages).

Taxa		Stream Station and Density	SAM
TRI:	Brachycentridae*	UHWC-D: 1.1t	0.03
	Glossosomatidae*	TR-PBB: 1.1t	0.03
	Culoptila	LRsb-R: 21.5	0.6
	Helicopsyche	TR-ShD: 64.6; TR-PBB: 73.2; EFHWC: p	3.9
	Potamyia	Indian: 2.2	0.06
	Hydroptilidae*	TR-PBB: 371.2	10.6
	Leptoceridae*	TR-PBB: 3.2	0.09
	Nectopsyche	TR-ShD; 3.2; TR-PBB: 432.6	12.5
	Limnephilidae*	LOtr-A: 1.1	0.03
	Glyphopsyche	Lame Dr: 5.4	0.2
	Psychoglypha	Cow-O: 10.8	0.3
	Ptilostomis	Davis: 3.2; Logging: 29.1; Reserv: 6.5	1.1
	Neureclipsis	UOtr-O: 1.1t	0.03
OST:	Ostracoda*	------------	--
AMP:	Gammarus	Indian: 7.5; Lame Dr: 365.8;	10.7
ACA:	Acari*	------------	--
HIR:	Percymoorensis marmoratis	Beaver: 6.5t	0.2
	Erpobdellidae*	Lame Dr: 59.2; Beaver: 15.1	2.1
	Dina anoculata	Beaver: 8.6t	0.2
	Erpobdella	Beaver: 17.2	0.5
	Glossiphoniidae*	UOtr-O: 15.1	0.4
	Batracobdella	Beaver: 8.6t	0.2
	Placobdella	Beaver: 6.5	0.2
OLI:	Oligochaeta*	------------	--
GAS:	Physidae*	LOtr-A: 3.2	0.09
PEL:	Pelecypoda*	TR-PBB: p; LHWC-B: p; LOtr-A: p	p
	Unionidae*	LHWC-B: 1.1	0.03
TUR:	Turbellaria*	------------	--
NEM:	Nematoda*	------------	--
NMT:	Nematomorpha*	------------	--

*Denotes the collection of a higher taxa representative that could not be identified to the generic level.

are organized on the basis of the higher systematic levels such as order and class, and the arrangements of the individual items in this table closely correspond to the sequence of taxa presented in Table 7. The three-letter symbols that are used as taxa markers in Table 8 have also been defined in this earlier summary. The "t" designations in Table 8 denote the occurrence of a tentative taxonomic identification, and the "p" notations indicate the probable presence of a particular taxa at a sampling station even though intact individuals could not be found in the associated samples. That is, the presence of a taxa was inferred from the identification of empty shells, cases, and exoskeletons, but these fragments were not counted as a part of the density determinations. In addition, the different life stages of the macroinvertebrates (adult, larvae, and pupae) were recognized during the laboratory work whenever feasible, and the density values that are tabulated in the project data report have been segregated according to these stages for the appropriate organisms. However, since no discussions will be directed to the life cycle features of the macroinvertebrates in this writing, the separate sets of life stage data for an organism have been summed as one density value for presentation in this interpretive report.

Data Evaluations. By definition, an alternate grouping to the minor taxa are the major macroinvertebrate forms, and this latter category typically contains the more dominant and the more ubiquitous types of organisms that were collected during the field work. With reference to this second group, the minor taxa of the inventory as summarized in Table 8 possess one obvious and distinctive characteristic than separates them from the major category, and this distinguishing feature relates to the comparatively low mean study area density levels of most of the minor organisms; these densities can approach values as low as 0.03 individuals per square meter (N/m^2) across all of the streams. About 88% of the minor listings had mean project region densities less than 1.5 N/m^2, and this set of organisms demonstrated an average mean density of only 1.1 N/m^2 for each of the listings in contrast to a more typical value of 116 N/m^2 for the other organisms. The low study area densities of the minor taxa group are due in part to the fact that they were collected at only a few stations, but three other aspects also come into play as described below.

First, a large number of the minor listings denote non-discrete taxa that are representative of a few individuals of a higher systematic series that could not be identified to a lower taxonomic level (e.g., Empididae, Sialidae, Zygoptera, and Brachycentridae). A high density, thereby, would not be anticipated in these cases since a major portion of the specimens could be carried to a generic name and classified as a member of the major taxa group. Second, many of the listings in Table 8 are indicative of discrete taxa (keyed to the lowest level possible), but since some of the discrete taxa consist of the non-benthic organisms that have swimming, diving, climbing, littoral, or semiaquatic characteristics (e.g., Dytiscidae, Heteroceridae, Dixa, Corixidae, Homoptera, and Aeshna), numerous individuals of this group would not be expected to occur in a benthic collection. As a third factor, although most of the remaining discrete taxa in Table 8 can be classified as truly benthic forms, these organisms were still observed to be at extremely low densities in the project region streams (e.g., Zaitzevia parvula, Culicoides, Rithrogena, Culoptila, and the plecopterans) simply because they cannot be found in high populations

under the particular blend of environmental conditions that happen to characterize the study area waters. This implies that severe limiting factors of some kind must be affecting these particular animals.

Because of the inventory's collection techniques and the large number of samples, the density estimates in Table 8 for the minor benthic organisms appear to be fairly accurate representations of their abundance levels in the southern Fort Union region. Therefore, these macroinvertebrates can be further categorized as being relatively rare in the streams, and they are probably not very important ecologically as a result of their general scracity. However, similar conclusions cannot be directed to the non-discrete taxa or to the non-benthic forms because of the incompleteness of the information. That is, the inventory data might point to the relative stream bottom activities of the non-benthic organisms, but this same data is not illustrative of the actual abundance of these macroinvertebrates in a stream since other types of habitats were not directly sampled in the main core of the project. For example, Table 8 suggests that *Aeshna* is relatively rare in benthic habitats, but this dragonfly larvae could be quite abundant amongst the plant materials of an undercut bank since this would be a more conducive habitat with reference to this larvae's climbing requirements.

A few exceptions to the low density characteristics of the minor taxa are evident in Table 8 where a small selection of these macroinvertebrates demonstrated densities above 1.5 N/m^2 and approaching 21 N/m^2. Such taxa describe a few novel organisms that were absent or rare at most of the sampling sites but relatively abundant at one (or two) of the locations. This single-station abundance, then, causes an elevation in their overall density means. Examples of these animals are *Ormosia* in Deer Creek, *Ephemerella* in the Tongue River, *Nectopsyche* at the TR-PBB site, and *Gammarus* in Lame Deer Creek, among others. Although largely insignificant from a study area perspective, this type of macroinvertebrate is probably ecologically important in those streams where they do show a high density level.

Although the minor taxa are not extremely abundant in the study area, they do contribute to the lotic faunal richness of the region since about one-half of the discrete taxa collected from the streams can be relegated to this taxa group. However, these macroinvertebrates do not make a major contribution to the faunal diversities of the individual sampling stations since an average of only 4.2 minor taxa, ranging between zero and nine, were identified at most of the sites. This mean value corresponds to about 13% of the total taxa count that was typically obtained at those stations having more than four collections. The one exception to this observation was found at the TR-PBB location which provided 18 minor taxa equalling 42% its total taxa count, and this feature points to the general faunal uniqueness of this mainstem river in relation to the smaller streams of the region.

Major Taxa

Tabular Considerations. The major macroinvertebrate taxa of the coalfield area streams have been defined as those organisms that were identified in the benthic samples from four or more of the sampling stations described

in Tables 1 and 2. The mean abundance-densities of these major macroinvertebrates for each of the sampling sites are summarized by taxa in a series of six tables that are organized on the basis of drainage basins (Figure 1) as follows: Table 9--seven stream stations in the Rosebud Creek drainage; Table 10--six stream stations in the upper Tongue River drainage above the Pyramid Butte site; Table 11--one station on the Tongue River and five stations on small streams in the middle Tongue River drainage in the vicinity of the Pyramid Butte site and downstream to Ashland-Brandenberg; Table 12--seven stream stations in the Hanging Woman Creek and Otter Creek drainages; Table 13--one stream station in the lower Tongue River drainage (Pumpkin Creek) and five stream stations on small tributaries to the Yellowstone River; and Table 14--three stream stations in the Powder River drainage.

Tables 9 to 14 also list the total mean macroinvertebrate abundance of each station as a sum of the taxa densities, which includes the minor forms, and similar to Table 8, Table 14 presents the mean study area densities of each of the major taxa as averaged across the 35 macroinvertebrate sampling sites (Table 1). All of the accessory descriptions that were directed to the contents of Table 8 are also applicable to the six major data tables.

Study Area Evaluations. As indicated in Tables 9 to 14, most of the major listings represent discrete taxa that were keyed to the lowest systematic level possible within the confines of the project, and many of these organisms can be classified as true benthic forms in having sprawling, clinging, and burrowing habits. Because of the inventory's sampling techniques, the taxa in these tables thereby represent the more important and dominant kinds of macroinvertebrates that were collected from the study area streams. Of the discrete listings in Table 14, 84% demonstrated mean study area densities in excess 1.5 N/m^2 with a typical value of 116 N/m^2, while 22% had densities greater than 60 N/m^2 with a few of the extremely abundant organisms (6%) having mean densities above the 1000 N/m^2 level. However, 16% of the discrete major taxa had mean study area densities less than 1.5 N/m^2, and along with most of the minor forms, these organisms can also be viewed as ecologically unimportant in the coalfield waters.

By combining the data in Tables 8 and 14, the following abundance classification system was developed for the minor and major macroinvertebrates along with the taxa percentages and a few associated examples: (I) the very abundant major taxa (3.1% of the discrete taxa total) with mean densities exceeding 1036 N/m^2 and approaching 2875 N/m^2 (Chironomidae, Simulium, and Hydropsychidae); (II) the abundant major taxa (7.8%) with densities between 64 and 305 N/m^2 (three of the riffle beetle genera, Baetis-Caenis, Brachycentrus, Hydroptila, Hyalella azteca, and Physa); (III) the very common major taxa and Ephemerlla (13.2%) with densities between 13 and 33 N/m^2 (Stenelmis, Hemerodromia, Tricorythodes, Hesperophylax, Turbellaria, and so on); (IV) the somewhat common taxa (27.9%) with densities between 1.5 and 13 N/m^2 (a few of the minor taxa along with Agabus, Euparyphus, Pseudocloeon, Sialis Ithytrichia, Gyraulus, and so on); and (V) the rare taxa (48.1%) with mean densities less than 1.5 N/m^2 (most of the minor taxa plus Helichus, Berosus, Chrysops, Hetaerina, Oncocosmoecus-Polycentropus, Ferrissia, and Nematomorpha).

Table 9. Mean sampling station abundance-density of major macroinvertebrate taxa (numbers of individuals per square meter) collected from natural stream substrates and average station totals in the Rosebud Creek drainage of southeastern Montana (the first page of two pages).

	Taxa	URsb-K	MRsb-C	LRsb-R	Indian	Davis	Muddy	LameDr
COL:	Helichus sp.	--	--	--	--	--	--	--
	H. striatus	--	--	--	--	--	--	--
	Agabus	1.1	--	--	3.2	10.8	--	--
	Dubiraphia sp.	26.9	43.0	--	11.8	219.5	180.8	14.0
	D. vittata	--	--	--	--	93.6	--	69.9
	Microcylloepus sp.	26.9	118.4	43.0	59.2	--	21.5	5.4
	M. pusillus	--	3.2	--	7.5	--	--	--
	Optioservus sp.	32.3	--	--	699.4	--	8.6	322.8
	O. divergens	4.3	--	--	53.8	--	--	5.4
	O. quadrimaculatus	1.1	--	--	10.8	--	--	--
	Stenelmis sp.	--	46.3	--	--	--	--	--
	S. sinuata	--	3.2	--	--	--	--	--
	S. vittipennis	--	3.2	--	--	--	--	--
	Haliplus	--	--	--	--	--	--	5.4
	Berosus	--	--	--	7.5	--	--	--
DIP:	Clinocera-Chelifera	20.4t	--	--	50.6t	39.8t	--	5.4t
	Hemerodromia	52.7t	7.5t	172.2t	53.8t	--	--	--
	Euparyphus	--	--	--	2.2	--	--	--
	Chrysops	--	--	--	--	3.2	--	--
	Tananus	--	--	--	--	3.2	--	--
	Muscidae*	--	--	--	21.5	--	--	--
	Limnophora	--	--	--	--	--	--	--
	Ceratopogonidae*	--	--	--	--	--	--	--
	Bezzia-Probezzia	4.3	--	--	2.2	10.8	3.2	--
	Bezzia-Probezzia-Palpomyia	--	--	--	--	--	--	--
	Palpomyia	--	--	--	--	--	--	--
	Chironomidae*	3808.0	190.5	3895.1	6501.2	4124.3	1794.8	3636.9
	Simulium	30.1	93.6	2431.8	502.5	107.6	159.2	1687.2
	Dicranota	1.1	--	--	182.9	--	32.3	21.5
	Tipula	3.2	10.8	--	10.8	3.2	--	--
EPH:	Baetidae*	--	--	--	p	--	--	--
	Baetis	253.9	57.0	--	109.8	50.6	182.9	75.3
	Pseudocloeon	--	7.5	--	--	--	--	--
	Caenis	--	--	--	107.6	64.6	156.0	5.4
	Heptageniidae	3.2	--	--	--	--	--	--
	Leptophlebiidae	4.3	--	--	--	--	--	--
	Choroterpes	--	7.5	322.8	--	--	5.4	--
	Choroterpes-Leptophlebia	--	93.6	--	--	--	--	--
	Tricorythodes	122.7	14.0	21.5	7.5	--	--	--

*Denotes the collection of a higher taxa representative that could not be identified to the generic level.

Table 9. Continued (the second page of two pages).

Taxa		URsb-K	MRsb-C	LRsb-R	Indian	Davis	Muddy	LameDr
HEM:	Heteroptera*	--	--	--	--	6.5t	--	--
	Ambrysus mormon	--	46.3	--	--	--	86.1	--
LEP:	Parargyractis	--	--	21.5	--	--	--	--
MEG:	Sialis	1.1	--	--	--	72.1	--	--
ANI:	Ophiogomphus	3.2	3.2	--	12.9	--	--	--
ZYG:	Hetaerina sp.	--	--	--	--	--	--	--
	H. americana	--	--	--	--	--	--	--
	Coenagrionidae	--	--	--	--	7.5	--	--
	Argia sp.	--	--	--	--	--	--	--
	Argia vivida	--	--	--	--	--	--	--
	Ischnura	--	--	--	--	3.2	--	64.6
PLE:	Isoperla	8.6	--	--	3.2	--	--	--
TRI:	Brachycentrus	289.4	39.8	--	852.2	--	8.6	688.6
	Cheumatopsyche	1310.6	487.4	1398.8	7230.7	602.6	1703.3	6859.5
	Hydropsyche	1419.2	168.9	3593.8	2827.7	--	40.9	659.6
	Hydroptila	410.0	--	107.6	403.5	3.2	226.0	215.2
	Ithytrichia	--	3.2	--	--	--	--	--
	Ochrotrichia	11.8	--	--	7.5	--	--	--
	Oecetis	--	--	--	5.4	--	5.4	43.0
	Hesperophylax	--	--	--	--	82.9	--	64.6
	Limnephilus	--	--	--	--	3.2	--	--
	Onocosmoecus	--	--	--	3.2	--	3.2	--
	Polycentropus	--	--	--	--	--	--	--
OST:	Ostracoda*	--	--	--	--	24.7	--	--
AMP:	Hyalella azteca	1.1	--	--	82.9	244.3	864.0	1737.7
ACA:	Acari*	63.5	3.2	--	263.6	14.0	53.8	26.9
HIR:	Hirudinea*	1.1	3.2	--	--	--	--	--
	Glossiphonia sp.	--	--	--	--	3.2	--	16.1
	G. complanata	--	--	--	--	--	3.2	--
	Helobdella sp.	--	--	--	--	--	83.9	--
	H. stagnalis	--	--	--	--	--	46.3	10.8
OLI:	Oligochaeta*	46.3	32.3	--	61.3	50.6	59.2	3.2
GAS:	Gastropoda*	--	--	--	--	--	--	--
	Ferrissia	1.1	p	--	--	--	--	--
	Lymnaea	--	--	--	2.2	--	p	--
	Gyraulus	p	--	--	61.3	p	p	--
	Helisoma	--	--	--	--	--	p	10.8
	Physa	1.1	3.2	21.5	p	100.1	40.9	35.5
	Columnella	--	--	--	p	--	--	--
PEL:	Pisidium	6.5	--	--	5.4	--	91.5	32.3
	Sphaerium	--	14.0	--	--	--	--	--
TUR:	Turbellaria*	--	39.8	--	--	--	--	--
NEM:	Nematoda*	--	--	--	--	--	16.1	--
NMT:	Nematomorpha*	--	--	--	--	--	--	--
Minor Taxa		7.6	20.4	43.0	49.5	92.4	--	496.1
Station Totals		7978.7	1564.2	12072.6	20278.3	6042.7	5877.1	16819.1

*Denotes the collection of a higher taxa representative that could not be identified to the generic level.

Table 10. Mean sampling station abundance-density of major macroinvertebrate taxa (numbers of individuals per square meter) collected from natural stream substrates and average station totals in the upper Tongue River drainage of southeastern Montana (the first page of two pages).

	Taxa	TR-ShD	Ash	Youngs	Sqrrl	Deer	Canyon
COL:	Helichus sp.	--	--	--	2.2	--	--
	H. striatus	--	--	--	1.1	--	--
	Agabus	--	--	--	--	6.5	--
	Dubiraphia sp.	3.2	57.0	21.5	402.4	--	93.6
	D. vittata	--	--	--	19.4	--	--
	Micro-cylloepus sp.	514.3	28.0	16.1	52.7	--	78.5
	M. pusillus	64.6	--	5.4	--	--	--
	Optioservus sp.	--	14.0	16.1	398.1	--	--
	O. divergens	--	--	--	46.3	--	--
	O. quadri-maculatus	--	--	--	43.0	--	--
	Stenelmis sp.	24.7	--	--	--	--	--
	S. sinuata	21.5	--	--	--	--	--
	S. vittipennis	5.4	--	--	4.3	--	--
	Haliplus	--	--	--	--	--	50.6
	Berosus	--	--	--	--	--	7.5
DIP:	Clinocera-Chelifera		43.0t	5.4t		--	--
	Hemerodromia	3.2t	--	21.5t	265.8t	--	--
	Euparyphus	--	--	--	--	--	287.3
	Chrysops	--	--	--	--	--	--
	Tabanis	--	--	--	--	14.0	--
	Muscidae*	--	201.2	--	--	--	14.0
	Limnophora	--	--	--	4.3t	--	--
	Ceratopogonidae*	--	--	--	--	--	--
	Bezzia-Probezzia	8.6	86.1	--	50.6	43.0	43.0
	Bezzia-Probezzia-Palpomyia	14.0	--	--	38.7	14.0	--
	Palpomyia	--	--	--	38.7	14.0	--
	Chironomidae*	1644.1	7650.4	1673.2	14963.9	982.4	401.3
	Simulium	568.1	706.9	69.9	196.9	10.8	1578.5
	Dicranota	--	287.3	--	9.7	--	--
	Tipula	--	7.5	--	6.5	--	--
EPH:	Baetidae*	--	--	--	14.0	--	50.6
	Baetis	1030.8	939.3	48.4	17.2	--	21.5
	Pseudocloeon	69.9	46.3	--	--	--	--
	Caenis	--	--	--	1.1	3.2	7.5
	Heptageniidae	10.8	--	--	--	--	--
	Leptophlebiidae	3.2	p	--	4.3	--	7.5
	Choroterpes	--	--	--	--	--	--
	Choroterpes-Leptophlebia	10.8	--	--	--	--	--
	Tricorythodes	59.2	--	10.8	--	--	7.5

*Denotes the collection of a higher taxa representative that could not be identified to the generic level.

Table 10. Continued (the second page of two pages).

	Taxa	TR-ShD	Ash	Youngs	Sqrl	Deer	Canyon
HEM:	Heteroptera*	--	--	--	--	3.2	--
	Ambrysus mormon	--	--	--	52.7	--	--
LEP:	Parargyractis	57.0	--	--	29.1	--	--
MEG:	Sialis	--	--	--	--	--	--
ANI:	Ophiogomphus	10.8	3.2	10.8	--	--	7.5
ZYG:	Hetaerina sp.	--	--	--	--	--	--
	H. americana	--	--	--	--	--	--
	Coenagrionidae	--	--	--	--	3.2	21.5
	Argia sp.	--	--	--	--	43.0	43.0
	Argia vivida	--	--	--	--	--	--
	Ischnura	--	--	--	--	24.7	--
PLE:	Isoperla	24.7	--	--	--	--	--
TRI:	Brachycentrus	202.3	29.1	43.0	31.2	--	--
	Cheumatopsyche	1428.9	1423.5	1033.0	8644.6	3.2	681.1
	Hydropsyche	2114.3	2528.6	1468.7	12182.5	--	78.5
	Hydroptila	80.7	215.2	129.1	215.2	--	--
	Ithytrichia	--	--	--	--	--	7.5
	Ochrotrichia	46.3	29.1	10.8	14.0	--	--
	Oecetis	127.0	p	--	--	--	--
	Hesperophylax	--	--	--	--	--	--
	Limnephilus	--	--	--	--	186.1	--
	Onocosmoecus	--	14.0	10.8	--	--	--
	Polycentropus	--	--	--	--	--	--
OST:	Ostracoda*	--	--	--	p	--	21.5
AMP:	Hyalella azteca	-	--	--	19.4	107.6	136.7
ACA:	Acari*	--	43.0	--	273.3	7.5	21.5
HIR:	Hirudinea*	--	--	--	--	--	7.5
	Glossiphonia sp.	--	--	--	--	--	--
	G. complanata	--	--	--	--	--	--
	Helobdella sp.	--	--	--	--	--	--
	H. stagnalis	--	--	--	--	--	--
OLI:	Oligochaeta*	83.9	3.2	10.8	29.1	82.9	7.5
GAS:	Gastropoda*	--	--	--	--	--	--
	Ferrissia	--	--	--	--	--	--
	Lymnaea	--	--	p	--	21.5	--
	Gyraulus	p	--	p	p	3.2	--
	Helisoma	--	--	--	--	--	86.1
	Physa	--	86.1	21.5	14.0	46.3	--
	Columnella	--	--	--	--	--	--
PEL:	Pisidium	5.4	--	p	--	--	--
	Sphaerium	p	--	--	--	--	--
TUR:	Turbellaria*	301.3	--	--	--	--	64.6
NEM:	Nematoda*	--	--	--	23.7	--	--
NMT:	Nematomorpha*	--	--	--	--	--	--
Minor Taxa		293.7	14.0	--	1.1	174.3	--
Station Totals		8832.7	14456.0	4626.8	38111.1	1794.6	3833.4

*Denotes the collection of a higher taxa representative that could not be identified to the generic level.

Table 11. Mean sampling station abundance-density of major macroinvertebrate taxa (numbers of individuals per square meter) collected from natural stream substrates and average station totals in the middle Tongue River drainage of southeastern Montana (the first page of two pages).

	Taxa	TR-PBB	PrDog	Bull	Cook	Logging	Beaver
COL:	Helichus sp.	--	--	--	--	--	--
	H. striatus	--	--	--	7.5	--	--
	Agabus	--	10.8	--	24.7	--	--
	Dubiraphia sp.	71.0	--	64.6	7.5	2159.5	56.0
	D. vittata	3.2	--	--	35.5	--	--
	Microcylloepus sp.	3304.4	10.8	--	7.5	--	--
	M. pusillus	804.8	--	--	--	--	8.6
	Optioservus sp.	--	75.3	--	--	--	--
	O. divergens	--	--	--	--	--	--
	O. quadrimaculatus	--	--	--	--	--	--
	Stenelmis sp.	289.4	--	--	--	--	--
	S. sinuata	12.9	--	--	--	--	--
	S. vittipennis	26.9	--	--	--	--	--
	Haliplus	--	--	--	14.0	--	47.3
	Berosus	--	--	--	--	--	--
DIP:	Clinocera-Chelifera	--	--	--	--	--	2.2t
	Hemerodromia	17.2t	21.5t	53.8t	--	--	23.7t
	Euparyphus	--	--	--	--	--	--
	Chrysops	--	--	--	--	--	--
	Tabanus	--	--	--	--	21.5	--
	Muscidae*	--	--	--	43.0	--	4.3
	Limnophora	--	--	--	--	--	--
	Ceratopogonidae*	5.4	--	--	--	7.5	--
	Bezzia-Probezzia	45.2	--	10.8	43.0	--	17.2
	Bezzia-Probezzia-Palpomyia	2.2	--	--	--	86.1	8.6
	Palpomyia	--	--	--	29.1	--	--
	Chironomidae*	3254.9	430.4	2259.6	11029.0	717.7	2771.8
	Simulium	688.6	43.0	419.6	1969.1	182.9	99.0
	Dicranota	3.2	--	--	--	--	--
	Tipula	--	--	--	32.3	132.3	--
EPH:	Baetidae*	371.2	--	--	--	--	--
	Baetis	1276.1	182.9	473.4	115.1	32.3	--
	Pseudocloeon	9.7t	--	--	--	--	--
	Caenis	--	21.5	--	7.5	107.6	378.8
	Heptageniidae	23.7	--	--	--	--	--
	Leptophlebiidae	3.2	--	--	--	--	--
	Choroterpes	99.0	--	--	--	--	--
	Choroterpes-Leptophlebia	266.8	--	--	--	--	--
	Tricorythodes	341.1	--	32.3	--	--	2.2

*Denotes the collection of a higher taxa representative that could not be identified to the generic level.

Table 11. Continued (the second page of two pages).

Taxa		TR-PBB	PrDog	Bull	Cook	Logging	Beaver
HEM:	Heteroptera*	--	--	--	--	3.2	--
	Ambrysus mormon	30.1	--	--	--	--	30.1
LEP:	Parargyractis	24.7	--	32.3	--	--	--
MEG:	Sialis	--	--	--	--	3.2	--
ANI:	Ophiogomphus	1.1	--	--	--	--	--
ZYG:	Hetaerina sp.	--	--	--	--	--	--
	H. americana	--	--	--	--	--	--
	Coenagrionidae	--	--	--	--	--	8.6
	Argia sp.	--	86.1	10.8	14.0	--	--
	Argia vivida	--	--	--	--	--	--
	Ischnura	--	--	--	--	43.0	30.1
PLE:	Isoperla	43.0	--	--	--	--	--
TRI:	Brachycentrus	--	--	75.3	--	--	--
	Cheumatopsyche	189.4	677.9	1872.2	4002.7	702.6	9877.7
	Hydropsyche	1343.9	484.2	3862.8	7.5	7.5	15.1
	Hydroptila	348.6	226.0	--	172.2	24.7	58.1
	Ithytrichia	--	--	--	--	--	--
	Ochrotrichia	162.5	--	--	--	--	--
	Oecetis	108.7	--	--	--	--	--
	Hesperophylax	--	--	--	--	--	--
	Limnephilus	--	--	--	--	--	--
	Onocosmoecus	--	--	--	--	--	--
	Polycentropus	--	--	--	--	--	--
OST:	Ostracoda*	1.1	--	--	--	7.5	--
AMP:	Hyalella azteca	--	290.5	--	158.2	7.5	2737.3
ACA:	Acari*	11.8	--	32.3	21.5	46.3	47.3
HIR:	Hirudinea*	--	--	--	--	3.2	--
	Glossiphonia sp.	--	--	--	--	14.0	--
	G. complanata	--	--	--	14.0	--	68.9
	Helobdella sp.	--	--	--	--	--	--
	H. stagnalis	--	--	--	--	--	886.6
OLI:	Oligochaeta*	16.1	--	--	341.1	7.5	21.5
GAS:	Gastropoda*	p	--	--	--	p	--
	Ferrissia	p	--	--	--	--	--
	Lymnaea	--	--	--	--	p	--
	Gyraulus	--	--	10.8	7.5	p	p
	Helisoma	--	--	--	--	--	--
	Physa	107.6	839.3	10.8	35.5	86.1	43.0
	Columnella	pt	--	--	--	pt	--
PEL:	Pisidium	2.2	--	--	14.0	322.8	--
	Sphaerium	--	--	--	--	--	--
TUR:	Turbellaria*	308.8	--	--	--	--	--
NEM:	Nematoda*	--	--	--	--	10.8	--
NMT:	Nematomorpha*	--	--	--	3.2	--	--
Minor Taxa		1932.6	21.6	--	101.1	110.7	71.1
Station Totals		15552.3	3421.8	9221.4	18257.3	4848.0	17315.1

*Denotes the collection of a higher taxa representative that could not be identified to the generic level.

Table 12. Mean sampling station abundance-density of major macroinvertebrate taxa (numbers of individuals per square meter) collected from natural stream substrates and average station totals in the Hanging Woman Creek and Otter Creek drainages of southeastern Montana (the first page of two pages).

	Taxa	UHWC-D	LHWC-B	EFHWC	Bear	UOtr-O	Cow-O	LOtr-A
COL:	Helichus sp.	--	--	--	--	--	--	--
	H. striatus	--	--	2.2	--	--	5.4	--
	Agabus	--	1.1	1.1	57.0	11.8	43.0	--
	Dubiraphia sp.	18.3	28.0	6.5	--	86.1	--	2.2
	D. vittata	1.1	--	--	--	--	--	--
	Microcylloepus sp.	40.9	115.1	1.1	--	21.5	--	273.3
	M. pusillus	21.5	9.7	--	--	--	--	1.1
	Optioservus sp.	--	--	5.4	--	--	1495.6	--
	O. divergens	--	--	--	--	--	64.6	--
	O. quadrimaculatus	--	--	--	--	--	59.2	--
	Stenelmis sp.	1.1	8.6	1.1	--	--	--	68.9
	S. sinuata	--	--	--	--	--	--	--
	S. vittipennis	--	--	--	--	--	--	--
	Haliplus	--	--	--	3.2	3.2	--	--
	Berosus	--	--	--	--	--	--	--
DIP:	Clinocera-Chelifera	--	--	3.2t		--	--	3.2t
	Hemerodromia	10.8t	35.5t	1.1t	7.5t	6.5t	--	28.0t
	Euparyphus	--	--	8.6	3.2	--	--	1.1
	Chrysops	--	--	--	--	7.5	--	1.1
	Tabanus	2.2	--	1.1	7.5	--	--	--
	Muscidae*	--	--	2.2	222.7	61.3	--	--
	Limnophora	4.3t	--	--	86.1t	54.9t	--	--
	Ceratopogonidae*	--	1.1	--	--	--	--	--
	Bezzia-Probezzia	6.5	17.2	15.1	7.5	63.5	--	39.8
	Bezzia-Probezzia-Palpomyia	--	--	2.2	--	--	--	--
	Palpomyia	1.1	1.1	--	--	3.2	--	--
	Chironomidae*	853.3	2131.6	178.6	3289.3	8970.6	129.1	4834.5
	Simulium	2836.3	6833.7	713.4	2338.1	17789.5	285.1	3450.7
	Dicranota	--	4.3	23.7	--	18.3	32.3	--
	Tipula	--	--	60.3	--	--	--	--
EPH:	Baetidae*	--	--	3.2	--	--	--	--
	Baetis	1.1	10.8	365.8	--	6.5t	586.4	1.1
	Pseudocloeon	--	--	--	--	--	--	--
	Caenis	30.1	57.0	--	--	85.0	--	33.4
	Heptageniidae	--	1.1	--	--	--	--	--
	Leptophlebiidae	--	--	--	--	--	--	--
	Choroterpes	--	3.2	--	--	--	--	--
	Choroterpes-Leptophlebia	1.1	--	--	--	--	--	--
	Tricorythodes	--	--	--	--	--	--	12.9

*Denotes the collection of a higher taxa representative that could not be identified to the generic level.

Table 12. Continued (the second page of two pages).

	Taxa	UHWC-D	LHWC-B	EFHWC	Bear	UOtr-O	Cow-O	LOtr-A
HEM:	Heteroptera*	--	--	--	--	--	--	--
	Ambrysus morman	9.7	11.8	--	--	17.2	--	14.0
LEP:	Parargyractis	--	5.4	--	--	--	--	3.2
MEG:	Sialis	1.1	4.3	2.2	--	9.7	--	--
ANI:	Ophiogomphus	--	--	--	--	--	--	--
ZYG:	Hetaerina sp.	11.8	1.1	--	--	--	--	12.9
	H. americana	2.2	--	--	--	--	--	2.2
	Coenagrionidae	3.2	--	--	7.5	--	--	--
	Argia sp.	--	--	1.1	--	20.4	5.4	--
	Argia vivida	--	--	1.1	--	--	--	--
	Ischnura	1.1	4.3	1.1	--	64.6	--	1.1
PLE:	Isoperla	--	--	--	--	--	--	--
TRI:	Brachycentrus	--	--	--	--	--	--	11.8
	Cheumatopsyche	2266.1	3785.4	328.2	118.4	1546.2	10.8	3366.8
	Hydropsyche	162.5	1014.7	123.7	--	3.2	--	229.2
	Hydroptila	4.3	17.2	1.1	308.8	570.3	--	437.9
	Ithytrichia	49.5	8.6	--	7.5	11.8	--	56.0
	Ochrotrichia	--	--	1.1	--	--	--	8.6
	Oecetis	--	--	--	--	--	--	--
	Hesperophylax	--	--	141.0	--	--	425.0	--
	Limnephilus	1.1t	--	--	--	--	--	--
	Onocosmoecus	--	--	--	--	--	--	--
	Polycentropus	5.4	1.1	1.1	--	1.1	--	--
OST:	Ostracoda*	--	3.2	--	7.5	--	--	--
AMP:	Hyalella azteca	17.2	1.1	5.4	61.3	1736.7	21.5	9.7
ACA:	Acari*	--	3.2	14.0	--	15.1	10.8	3.2
HIR:	Hirudinea*	--	--	2.2	--	1.1	--	3.2
	Glossiphonia sp.	--	--	--	--	--	--	--
	G. complanata	--	--	1.1	--	3.2	--	4.3
	Helobdella sp.	--	--	--	--	--	--	--
	H. stagnalis	--	--	--	--	11.8	--	8.6
OLI:	Oligochaeta*	30.1	4.3	59.2	43.0	43.0	5.4	16.1
GAS:	Gastropoda*	p	p	--	--	--	--	--
	Ferrisia	--	1.1	--	--	--	--	--
	Lymnaea	--	1.1	5.4	250.7	--	--	--
	Gyraulus	4.3	1.1	--	50.6	43.0	--	29.1
	Helisoma	--	--	--	--	4.3	--	3.2
	Physa	262.5	60.3	11.8	276.5	168.9	--	24.7
	Columnella	--	--	p	--	--	--	--
PEL:	Pisidium	--	1.1	15.1	--	14.0	10.8	--
	Sphaerium	--	1.1	p	--	--	--	--
TUR:	Turbellaria*	1.1	--	--	--	--	--	--
NEM:	Nematoda*	--	24.7	--	--	--	--	1.1
NMT:	Nematomorpha*	1.1	3.2	1.1	--	--	5.4	1.1
Minor Taxa		8.7	23.8	27.0	53.7	36.7	145.4	10.9
Station Totals		6672.7	14242.3	2139.9	7207.6	31511.7	3341.2	13010.2

*Denotes the collection of a higher taxa representative that could not be identified to the generic level.

Table 13. Mean sampling station abundance-density of <u>major</u> macroinvertebrate taxa (numbers of individuals per square meter) collected from natural stream substrates and average station totals in lower Pumpkin Creek and small tributaries to the Yellowstone River in southeastern Montana (the first page of two pages).

Taxa	Pmpkn	WFArm	LArm-F	Sweeny	Reserv	Sarpy
COL: *Helichus* sp.	--	--	--	--	--	--
H. striatus	--	--	--	--	--	--
Agabus	--	5.4	--	--	6.5	--
Dubiraphia sp.	1.1	--	--	26.9	21.5	261.5
D. vittata	--	--	--	--	--	--
Microcylloepus sp.	21.5	--	--	6.5	--	3.2
M. pusillus	--	--	--	--	--	--
Optioservus sp.	--	--	--	--	--	--
O. divergens	--	--	--	--	--	--
O. quadrimaculatus	--	--	--	--	--	--
Stenelmis sp.	--	--	--	--	--	--
S. sinuata	--	--	--	--	--	--
S. vittipennis	1.1	--	--	--	--	--
Haliplus	--	--	--	--	--	--
Berosus	--	5.4	--	19.4	--	--
DIP: *Clinocera-Chelifera*	--	--	--	--	--	--
Hemerodromia	35.5t	--	--	--	8.6t	8.6t
Euparyphus	--	--	--	--	--	--
Chrysops	--	--	--	--	25.8t	--
Tabanus	--	--	3.2	--	8.6	--
Muscidae*	--	--	--	--	--	--
Limnophora	--	--	--	--	--	--
Ceratopogonidae*	--	--	--	3.2	2.2	--
Bezzia-Probezzia	11.8	--	--	24.7	--	10.8
Bezzia-Probezzia-Palpomyia	--	--	10.8	--	94.7	--
Palpomyia	--	--	--	--	6.4	--
Chironomidae*	1377.3	726.3	516.5	710.2	2341.4	2340.3
Simulium	135.6	317.4	10.8	64.6	174.3	239.9
Dicranota	--	--	--	--	--	--
Tipula	--	--	--	3.2	--	--
EPH: Baetidae*	--	--	--	--	--	--
Baetis	35.5	--	--	--	2.2	3.2
Pseudocloeon	--	--	--	--	--	--
Caenis	111.9	10.8	405.7	118.4	15.1	40.9
Heptageniidae	--	--	--	--	--	--
Leptophlebiidae	--	--	--	3.2	--	3.2
Choroterpes	--	--	182.9	40.9	--	8.6
Choroterpes-Leptophlebia	--	--	--	--	--	--
Tricorythodes	--	--	--	--	2.2	--

*Denotes the collection of a higher taxa representative that could not be identified to the generic level.

Table 13. Continued (the second page of two pages).

	Taxa	Pmpkn	WFArm	LArm-F	Sweeny	Reserv	Sarpy
HEM:	Heteroptera*	--	--	--	--	--	--
	Ambrysus mormon	--	--	39.8	21.5	--	--
LEP:	Parargyractis	--	--	--	--	--	--
MEG:	Sialis	--	--	--	--	8.6	--
ANI:	Ophiogomphus	--	--	--	--	--	--
ZYG:	Hetaerina sp.	--	--	--	--	--	--
	H. americana	--	--	--	--	--	--
	Coenagrionidae	--	--	--	--	2.2	--
	Argia sp.	--	--	3.2	--	17.2	--
	Argia vivida	--	--	--	--	--	--
	Ischnura	--	16.1	7.5	--	322.8	5.4
PLE:	Isoperla	--	--	--	--	--	--
TRI:	Brachycentrus	--	--	--	--	--	--
	Cheumatopsyche	6957.4	--	330.3	299.1	4807.6	231.3
	Hydropsyche	1123.3	--	--	35.5	--	14.0
	Hydroptila	4.3	--	--	--	86.1	110.8
	Ithytrichia	30.1	--	32.3	35.5	--	--
	Ochrotrichia	--	--	--	--	--	--
	Oecetis	--	--	--	--	--	--
	Hesperophylax	--	--	--	--	--	--
	Limnephilus	--	--	--	--	2.2	--
	Onocosmoecus	--	--	--	--	--	--
	Polycentropus	--	--	3.2	--	--	--
OST:	Ostracoda*	--	--	--	--	6.5	--
AMP:	Hyalella azteca	9.7	5.4	--	--	2319.9	14.0
ACA:	Acari*	--	--	--	--	71.0	3.2
HIR:	Hirudinea*	--	--	--	--	8.6	--
	Glossiphonia sp.	--	--	--	--	--	--
	G. complanata	--	--	--	--	--	--
	Helobdella sp.	--	--	--	--	--	--
	H. stagnalis	--	--	--	--	--	--
OLI:	Oligochaeta*	8.6	--	3.2	5.4	47.3	19.4
GAS:	Gastropoda*	--	--	--	--	--	--
	Ferrissia	--	--	--	--	--	--
	Lymnaea	1.1t	64.6	--	--	--	--
	Gyraulus	--	--	--	--	6.5	--
	Helisoma	--	--	--	--	--	--
	Physa	3.2	--	416.4	102.2	2255.3	59.2
	Columnella	--	--	--	--	--	--
PEL:	Pisidium	--	--	--	--	71.0	--
	Sphaerium	--	--	--	--	--	--
TUR:	Turbellaria*	--	--	--	--	--	--
NEM:	Nematoda*	1.1	--	--	--	--	--
NMT:	Nematomorpha*	4.3	--	--	--	--	5.4
Minor Taxa		8.6	32.3	--	--	51.9	5.4
Station Totals		9883.0	1183.7	1965.8	1520.4	12794.2	3388.3

*Denotes the collection of a higher taxa representative that could not be identified to the generic level.

Table 14. Study area means (SAM) of the abundance-density of major macroinvertebrate taxa (numbers of individuals per square meter) collected from natural stream substrates and the mean abundance-density of major taxa and average sampling station totals in the Powder River drainage of southeastern Montana (the first page of two pages).

	Taxa	Mizpah	PR-Mo	PR-Mz	SAM
COL:	Helichus sp.	--	--	--	0.06
	H. striatus	--	--	--	0.5
	Agabus	--	--	--	5.2
	Dubiraphia sp.	--	--	--	111.0
	D. vittata	--	--	--	6.4
	Microcylloepus sp.	--	43.0	--	137.5
	M. pusillus	--	--	--	26.5
	Optioservus sp.	--	--	--	87.6
	O. divergens	--	--	--	5.0
	O. quadrimaculatus				3.3
	Stenelmis sp.	3.2	--	--	12.7
	S. sinuata	--	--	--	1.1
	S. vittipennis	--	--	--	1.2
	Haliplus	--	--	--	3.5
	Berosus	--	--	--	1.1
DIP:	Clinocera-Chelifera	--	--	--	4.9t
	Hemerodromia	5.4t	10.8t	--	24.3t
	Euparyphus	--	--	--	8.6
	Chrysops	--	--	--	1.1
	Tabanus	--	--	--	1.8
	Muscidae*	1.1	--	--	16.3
	Limnophora	--	--	--	4.3t
	Ceratopogonidae*	--	--	--	0.6
	Bezzia-Probezzia	1.1	--	--	16.2
	Bezzia-Probezzia-Palpomyia	11.8	--	--	8.1
	Palpomyia	--	--	--	2.7
	Chironomidae*	380.9	86.1	21.5	2874.8
	Simulium	87.2	3141.9	21.5	1428.2
	Dicranota	--	--	--	17.6
	Tipula	--	--	--	7.7
EPH:	Baetidae*	86.1	--	--	15.0
	Baetis	1.1	43.0	--	169.2
	Pseudocloeon	--	--	--	3.8
	Caenis	890.9	--	--	76.0
	Heptageniidae	1.1	--	--	1.1
	Leptophlebiidae	3.2	--	--	0.9
	Choroterpes	14.0	--	--	19.6
	Choroterpes-Leptophlebia	--	86.1	--	13.1
	Tricorythodes	--	--	--	18.1

*Denotes the collection of a higher taxa representative that could not be identified to the generic level.

Table 14. Continued (the second page of two pages).

Taxa		Mizpah	PR-Mo	PR-Mz	SAM
HEM:	Heteroptera*	1.1	--	--	0.4
	Ambrysus mormon	1.1	--	--	10.3
LEP:	Parargyractis	--	--	--	4.9
MEG:	Sialis	--	--	--	2.9
ANI:	Ophiogomphus	--	--	--	1.5
ZYG:	Hetaerina sp.	--	--	--	0.7
	H. americana	--	--	--	0.1
	Coenagrionidae	--	--	--	1.5
	Argia sp.	--	--	--	7.0
	Argia vivida	--	--	--	0.03
	Ischnura	8.6	--	--	17.1
PLE:	Isoperla	--	10.8	--	2.6
TRI:	Brachycentrus	--	--	--	64.9
	Cheumatopsyche	2317.7	2969.8	2883.7	2352.8
	Hydropsyche	91.5	645.6	43.0	1036.9
	Hydroptila	--	--	--	125.0
	Ithytrichia	19.4	--	--	7.5
	Ochrotrichia	--	--	--	8.3
	Oecetis	--	--	--	8.3
	Hesperophylax	--	--	--	20.4
	Limnephilus	--	--	--	5.5
	Onocosmoecus	--	--	--	0.9
	Polycentropus	3.2	--	--	0.4
OST:	Ostracoda*	--	--	--	2.1
AMP:	Hyalella azteca	54.9	--	--	304.1
ACA:	Acari*	--	--	--	30.0
HIR:	Hirudinea*	--	--	--	0.9
	Glossiphonia sp.	--	--	--	1.0
	G. complanata	--	--	--	2.7
	Helobdella sp.	--	--	--	2.4
	H. stagnalis	--	--	--	27.5
OLI:	Oligochaeta*	3.2	--	--	32.7
GAS:	Gastropoda*	--	--	--	p
	Ferrissia	--	--	--	0.06
	Lymnaea	--	--	--	9.9
	Gyraulus	--	--	--	6.2
	Helisoma	--	--	--	3.0
	Physa	4.3	--	--	146.8
	Columnella	--	--	--	p
PEL:	Pisidium	--	--	--	16.9
	Sphaerium	--	--	--	0.4
TUR:	Turbellaria*	--	--	--	20.4
NEM:	Nematoda*	--	--	--	2.2
NMT:	Nematomorpha*	--	--	--	0.7
Minor Taxa		5.4	43.0	--	110.9
Station Totals		3997.5	7080.1	2969.7	9537.5

*Denotes the collection of a higher taxa representative that could not be identified to the generic level.

These density-taxa percentage separations indicate that a large proportion of the organisms contributing to the faunal richness of the streams made only minor contributions to the total abundance of the macroinvertebrate associations; contrariwise, a relatively small set of dominant organisms, accounting for only a small fraction of the faunal diversity, provided a major part of the streams' benthic abundance levels. However, these abundance-diversity relationships are not unique to the aquatic macroinvertebrate associations of the southern Fort Union region since similar descriptions can be directed to many other types of biotic communities.

The abundant and very abundant taxa in Table 14 provided 94% of the total benthic densities in the project region, and these particular taxa therefore represent the most dominant benthic macroinvertebrates of the southern Fort Union streams. In addition, a statistically significant relationship (r = 0.63) was observed between an organism's density and its distributional features, i.e., the number of stations where it had been collected, and as a result, these same organisms were also relatively ubiquitous throughout the study region in being found at a large number of the sampling sites. The fourteen dominant taxa were identified at 25 of the 35 stations on the average, and two of the organisms (Chironomidae and Simulium) were collected at all of the locations. The common taxa, in contrast, were recognized at an average of ten stations, ranging from one to 29, while the rare taxa were largely non-ubiquitous and most typically found at only one or two of sites. This discussion suggests that many of the macroinvertebrates provide a patchy distribution across the study region in being found at a small set of stations while being absent or extremely rare in a large percentage of the streams. But superimposed on this patchwork pattern are the abundant and very abundant organisms that are found throughout most of the region, and these dominant organisms afford a faunal cohesion to the study area streams.

Table 15 lists the percent relative abundances (PRA) of the higher systematic categories of aquatic macroinvertebrares above the generic level. As indicated in this table, the Arthropoda had a distinctly high PRA of about 97% with the rest of the phyla (Annelida, Mollusca, Platyhelminthes, and Aschelmintes) providing only 3% of the total macroinvertebrate abundance. The gastropods proved to be the most dense of the non-arthropod groups, and the insects were by far the most prevalent of the arthropods. The markedly high PRA value of the Insecta suggests that these organisms are extremely important in the study area streams, not only from the standpoint of faunal richness, but also from the standpoint of total benthic abundance. Of the insects, the dipterans and the trichopterans made significant contributions both to faunal diversity as described previously and to macroinvertebrate numbers. In contrast, the coleopterans, which were the most significant of the macroinvertebrate groups in terms of stream diversity, were much less important in relation to their total numbers in the stream benthos. The ephemeropterans demonstrated a similar total density as the beetles, and the remaining insect orders, including the plecopterans, made only minor contributions to the total abundance levels. The stoneflies were most often observed in the larger streams while being absent (or extremely rate) from most of the smaller waters, and this distributional feature explains the low study region PRA value of this particular order.

Table 15. Percent relative abundances of the higher systematic categories of macroinvertebrates collected from natural stream substrates in the southern Fort Union region.

Phylum: Arthropoda	97.1 %
Class: Insecta	93.5 %
Order: Coleoptera	4.3 %
Family: Dytiscidae	0.07%
Elmidae	4.1 %
Haliplidae	0.04%
Nine Others	0.06%
Order: Diptera	46.4 %
Family: Empididae	0.31%
Stratiomyidae	0.10%
Muscidae	0.22%
Ceratopogonidae	0.29%
Chironomidae	30.1 %
Simuliidae	15.0 %
Tipulidae	0.31%
Six Others	0.10%
Order: Ephemeroptera	3.6 %
Family: Baetidae	2.0 %
Caenidae	0.80%
Ephemerellidae	0.21%
Leptophlebiidae	0.36%
Tricorythidae	0.19%
Four Others	<.01%
Order: Hemiptera	0.16%
Suborder: Heteroptera	0.16%
Family: Corixidae	0.04%
Gerridae	0.01%
Naucoridae	0.11%
Suborder: Homoptera	<.01%
Order: Lepidoptera	0.05%
Family: Pyralidae	0.05%
Order: Megaloptera	0.04%
Family: Sialidae	0.04%
Chauliodinae	<.01%
Order: Odonata	0.31%
Suborder: Anisoptera	0.03%
Family: Aeshnidae	0.01%
Gompidae	0.02%
Libellulidae	0.01%
Suborder: Zygoptera	0.28%
Family: Calopterygidae	0.01%
Coenagriondiae	0.27%
Order: Plecoptera	0.23%
Family: Nemouridae	0.04%
Perlidae	0.01%
Perlodidae	0.18%
Order: Trichoptera	38.4 %
Family: Brachycentridae	0.68%
Helicopsychidae	0.04%
Hydropsychidae	35.5 %
Hydroptilidae	1.6 %
Leptoceridae	0.22%
Limnephilidae	0.29%
Three Others	0.02%
Class: Crustacea	3.3 %
Subclass: Ostracoda*	0.02%
Subclass: Malacostraca	3.3 %
Order: Amphipoda	3.3 %
Family: Gammaridae	0.11%
Talitridae	3.2 %
Class: Arachnida	3.31%
Order: Acari*	0.31%
Phylum: Annelida	0.74%
Class: Hirudinea	0.40%
Family: Glossiphoniidae	0.36%
Two Others	0.04%
Class: Oligochaeta*	0.34%
Phylum: Mollusca	1.9 %
Class: Gastropoda	1.7 %
Family: Lymnaeidae	0.10%
Planorbidae	0.10%
Physidae	1.5 %
Two Others	<.01%
Class: Pelecypoda	0.18%
Family: Unionidae	<.01%
Sphaeriidae	0.18%
Phylum: Platyhelminthes	0.21%
Class: Turbellaria*	0.21%
Phylum: Aschelminthes	0.03%
Class: Nematoda*	0.02%
Class: Nematomorpha	0.01%
Order: Gordiida*	0.01%

*Denotes a higher taxa that could not be taken to family.

The following macroinvertebrate families were observed to be most abundant in the lotic systems of the project region (ranked in order of prevalence): (1) Hydropsychidae (macrocaddisfly larvae), (2) Chironomidae (midge larvae), (3) Simuliidae (black fly larvae and pupae), (4) Elmidae (riffle beetle larvae and adults), (5) Talitridae (common crustacean sideswimmers or scuds), (6) Baetidae (mayfly larvae), (7) Hydroptilidae (microcaddisfly larvae and pupae), (8) Physidae (pouch snails), (9) Caenidae (mayfly larvae), and (10) Brachycentridae (macrocaddisfly larvae). These ten families alone accounted for approximately 95% of the macroinvertebrate tabulations that were made during the project, and the chironomids and simulids accounted for 97% of the dipteran individuals and about 45% of the total study area densities.

Sampling Site Evaluations. The study area mean (SAM) densities in Tables 8 and 14 for each of the taxa point to the overall importance of the various organisms in relation to the entire project region, but potential variations in the importance of a taxa become evident on a sampling site basis in view of the density differences that can be observed among the many stations. For the very abundant macroinvertebrates, these inter-station density differences can be quite pronounced with the following ranges: Chironomidae--21.5 to 14,964 N/m^2, *Simulium*--10.8 to 17,790 N/m^2, *Cheumatopsyche*--3.2 to 9,878 N/m^2, and *Hydropsyche*--3.2 to 12,183 N/m^2. These ranges represent 700-fold to 3800-fold variations in taxa densities between the appropriate collection stations, and they do not consider the samples which failed to produce a particular organism. However, such ranges are sequentially less distinct for the abundant, very common, common, and rare taxa as illustrated by the following examples: abundant (e.g., *Caenis*)--1.1 to 891 N/m^2, an 810-fold difference; very common (e.g., *Tricorythodes*)--2.2 to 341 N/m^2, a 155-fold difference; common (e.g., *Gyraulus*) 1.1 to 61.3 N/m^2, a 56-fold difference; and rare (e.g., Nematomorpha)--1.1 to 5.4, a 4.9-fold difference. Many other examples of similar taxa density ranges for the five abundance classes are also available in the study data, and these inter-station abundance differences are due to two basic factors as described below.

First, variations in a taxon's density levels among the stations can be directly related to corresponding differences in the total macroinvertebrate abundances that are observed at the sampling sites as listed in Tables 9 to 14. That is, a macroinvertebrate might show a low density at a station in relation to the study area mean simply because these benthic organisms are not very abundant as a group at that stream location for a number of environmental reasons. In this total density dependence case, the importance or dominance of a taxon at a station might still be quite high in spite of its comparatively low density if the taxon happens to contribute to a high proportion of the station's total numbers as revealed by the macroinvertebrate's PRA value. For example, the mean Chironomidae density at the Youngs site was equal to 1,675 N/m^2 (Table 10) which is equivalent to 58% of the study area mean for this insect family. However, the total macroinvertebrate abundance at this site was only equal to 48% of the study area average so that the chironomid PRA of this stream location is actually quite close to the family's average PRA for the project region, i.e., 36.2% versus 30.1% respectively. As a result, the midges represent a dominant taxa in Youngs Creek in spite of their

comparatively low station densities. Other examples of this kind can also be found among the remaining abundant and very abundant taxa.

The aspect of total density dependence is also applicable to some of the less abundant macroinvertebrates as well as the more dominant forms where the density of a non-dominant taxon might also be dependent upon the total abundance of a site to some extent. But this factor is much less consistent, rigorous, and obvious for these low density organisms because of their small PRA's than it is for the abundant and very abundant animals. In general, most of the rare and common taxa, as defined on the basis of their mean study area abundances, probably fall into a second category that describes the general independence of a taxon's density level at any station from the total abundance characteristics of that site.

With respect to this second factor, a dominant taxon on a study area basis can demonstrate a relatively sparse density at a stream location regardless of the station's high or low total abundance levels simply because the macroinvertebrate does not fair well under the environmental conditions of the stream. This taxon, therefore, would not be important or dominant at that particular sampling site, and its density at this station would be less than that of a more typical site. In this total density independence case, the PRA of an abundant organism would be relatively low in the affected reach in relation to its study area mean, and this would point to the operation of a negative influence upon the taxon in that particular water. However, the converse can also be true with a taxon's station PRA greater than that for the study area as a whole, and this alternative is suggestive of a positive influence upon the organism. Numerous examples of both the positive and the negative independencies can be identified in the study data for the abundant and very abundant taxa at certain of the stations, and these can be identified by the wide plus or minus discrepancies that are found between the station and the study area PRA values. But if these two PRA's are fairly close as shown by the Youngs-Chironomidae example, then total density dependence is probably acting as the principal factor.

A few obvious negative examples of total density independence among the more abundant macroinvertebrates can be listed as follows, where "St" denotes the station PRA for a taxa and "SA" the study area value for the same organism: Baetis at the Reserv site (Table 13)--St = 0.02% versus SA = 1.8%; Cheumatopsyche at the Bear station (Table 12)--St = 1.6% versus SA = 24.7%; Simulium at the PrDog location (Table 11)--St = 1.3% versus SA = 15.0%; and Physa at the Bull station (Table 11)--St = 0.12% versus SA = 1.5%. Positive examples would include: Brachycentrus at the Indian location (Table 9)--St = 4.2% versus SA = 0.68%; Hyalella azteca at the LameDr site (Table 9)--St = 10.3% versus SA = 1.8%; Hydropsyche at the Sqrrl station (Table 10)--St = 32.0% versus 10.9%; and Microcylloepus at the TR-PBB site (Table 11)--St = 21.2% versus SA = 1.7%.

Stream Classification. In the main, a general independence of taxa density from total station abundance appears to be the most prevalent case in the inventory region among the more abundant organisms, and this is also true for the non-dominant forms. In view of the typically low PRA values of the common and rare taxa in relation to the high PRA's of the more prevalent macroinvertebrates, these low abundance organisms can be largely relegated

to the negative category of the independence group. However, a few of the common taxa were also observed to be fairly abundant and important at a few of the stream locations, showing a positive independence in these instances. In addition to the Nectopsyche and the other examples of this feature that were presented earlier for the minor taxa, Musidae at the Bear site (Table 12), Helobdella at the Beaver station (Table 11), Turbellaria in the Tongue River (Tables 10 and 11), and Pisidium in Logging Creek (Table 11) afford examples of this same occurrence among the less dense major taxa.

Because of this overall density independence, the macroinvertebrate taxa show a broad range of distributional and abundance patterns in the streams as illustrated in Tables 8 to 14, and the different study area waters show a fairly wide variation in the composition of dominant taxa that comprise their macroinvertebrate associations. Such compositional differences can be used to classify and fingerprint the streams and stations biologically, and a rather general classification system of this kind is presented in Table 16 where the streams and their macroinvertebrate associations have been named and segregated into seven classes according to their dominant taxa and/or to the unique abundance of an unusual form. Table 16 also summarized the total abundance characteristics of the different streams.

Numerous environmental and biological factors undoubtedly account for the variations in faunal composition that were identified among the sampling sites. However, since this writing focuses primarily upon the community aspects of the stream benthos and upon the effects of salinity on the streams' macroinvertebrate communities, no attempt will be made to assess these factors in this present report. Hopefully the opportunity will arise in the near future to undertake the faunal evaluations of this kind.

Total Station Densities

Typical Values and Data Comparisons. The total abundances of the macroinvertebrate associations at each of the sampling stations are presented in Tables 9 to 14, and these data along with some related sets of statistical information are summarized in Table 16. As indicated in this latter table, the average densities of the sites varied to a fair degree, ranging from a low of 1,184 N/m^2 at the WFArm location to a high of 38,111 N/m^2 at the Sqrrl station, and this range describes a 32-fold difference in this parameter across the study region. The study area mean for all of the sites was equal to 9,538 N/m^2 (Table 14) with a median value of 7,080 N/m^2. The relatively high mean/median ratio (1.35) suggests that a few stations with uniquely high densities (Sqrrl and UOtr-0) tended to weight the mean to the high side of the array to some extent, so the median value is probably more representative of the general macroinvertebrate density characteristics of the entire project region. In any event, both of these statistics indicate that most of the study area streams demonstrated significantly high levels of secondary production, although this feature was much more pronounced in some of the streams than in others.

For comparison, two studies are available which describe the benthic macroinvertebrate abundances of the Yellowstone River which is outside

Table 16. Biological classification of the study area streams relative to their dominant macroinvertebrate taxa and the total abundance characteristics of these streams (number of individuals per square meter from natural substrates).

Station Symbol	Sample Number	Sample Minimum	Sample Maximum	Station Mean	Station Median	Standard Deviation	Percent* Deviation
			HYDROPSYCHIDAE-CHIRONOMIDAE STREAMS				
MRsb-C	3	893	2,884	1,564	925	1,141	73.0
LRsb-R	1	--	--	12,073	--	--	--
Indian	6	2,851	79,624	20,278	6,499	29,940	147.6
TR-ShD	4	3,519	18,615	8,833	6,574	7,075	80.1
Youngs	2	2,281	6,972	4,627	4,627	3,317	71.7
Sqrrl	9	710	82,249	38,111	39,123	29,265	76.8
Bull	2	7,876	10,566	9,221	9,221	1,902	20.6
Pmpkn	8	43	60,299	9,883	872	20,962	212.1
Mizpah	8	43	19,712	3,998	468	6,929	173.3
PR-Mz	1	--	--	2,970	--	--	--
			CHIRONOMIDAE-HYDROPSYCHIDAE STREAMS				
URsb-K	14	11	29,913	7,979	5,940	7,981	100.0
Ash	3	420	29,870	14,456	13,084	14,773	102.2
Cook	3	3,508	42,394	18,257	8,866	21,076	115.4
			CHIRONOMIDAE-HYALELLA/PHYSA STREAMS				
Davis	3	1,291	11,341	6,043	5,509	5,046	83.5
Muddy	4	3,239	9,555	5,877	5,342	3,133	53.3
Deer	3	409	3,465	1,795	1,528	1,546	86.1
LArm-F	3	11	3,228	1,966	2,658	1,716	87.3
Sweeny	4	301	3,325	1,520	1,216	1,327	87.3
			HYDROPSYCHIDAE-HYALELLA/PHYSA STREAMS				
LameDr	4	1,108	45,579	16,819	10,287	19,659	116.9
PrDog	2	3,293	3,551	3,422	3,422	183	5.3
Beaver	5	6,359	41,361	17,315	12,385	13,766	79.5
Reserv	5	1,345	48,076	12,794	5,186	19,792	154.7
			ELMIDAE STREAMS				
TR-PBB	13	1,829	48,291	15,552	14,375	12,766	82.1
Logging	3	1,011	7,833	4,848	5,703	3,491	72.0
Cow-O	2	2,561	4,121	3,341	3,341	1,103	33.0
			SIMULIIDAE-HYDROPSYCHIDAE STREAMS				
Canyon	3	2,948	5,294	3,833	3,250	1,276	33.3
UHWC-D	14	968	19,981	6,673	4,632	6,292	94.3
LHWC-B	16	538	63,871	14,242	10,685	15,221	106.9
EFHWC	11	32	4,186	2,140	2,120	1,202	56.2
PR-Mo	1	--	--	7,080	--	--	--
			CHIRONOMIDAE/SIMULIIDAE STREAMS				
Bear	3	1,302	11,728	7,208	8,586	5,349	74.2
UOtr-O	7	1,001	120,555	31,512	25,533	41,148	130.6
LOtr-A	15	43	45,450	13,010	7,962	13,977	107.4
WFArm	2	624	1,743	1,184	1,184	791	66.8
Sarpy	4	183	5,810	3,388	3,766	2,519	74.4

*Percent deviation is defined as 100 times the standard deviation divided by the mean.

of the study area but is the main stream draining the lands in southeastern Montana (Figure 1). In one of these investigations (Karp, et al, 1977), densities ranging from 317 to 1737 N/m^2 were observed for the Yellowstone in the vicinity of Billings, Montana which is about 150 miles upstream from the coalfield region. The second study (Newell, 1977) provided somewhat similar values with an average density on the order of 1,400 N/m^2 for a long reach of the river from Big Timber to Sidney which encompasses the coalfield area. More specifically, a 1,100 mean was obtained in this same study for a small segment of the river that receives water directly from the Tongue River drainage (near Miles City).

As indicated by this extra-study data, almost all of the study area streams demonstrated higher mean macroinvertebrate densities than the Yellowstone River, and these differences become much more pronounced if the maximum values from the individual project samples are considered since counts in excess 40,000 and approaching 85,000 N/m^2 were obtained from the lower order streams on a few occasions. However, such high density levels are not particularly outstanding with reference to the observation of Merritt and Cummins (1978) that the Chironomidae family alone can afford larval densities of 50,000 N/m^2 in certain situations. Nevertheless, although not very close to some potential maximum abundance value, the study area waters did exhibit high secondary production characteristics, at least in relation to the Yellowstone River which can be used as a reference point. As a related observation, Baril, et al (1978), though using somewhat different field collection techniques that involved the modified Hess sampler, obtained fairly high total macroinvertebrate abundances for three stations along Rosebud Creek (an average of 6,421 N/m^2) that are closely similar to the Rosebud densities that were secured in this inventory for the same three locations (an average of 7,205 N/m^2).

Two stations were sampled on the Tongue River in order to afford the basis for a biological comparison between the creeks of the study area and the major stream within this region. As indicated in Table 16, the Tongue River also provided relatively high levels of macroinvertebrate abundance, and a fairly distinct, two-fold downstream increase in macroinvertebrate density became evident in the river from the upstream TR-ShD site to the TR-PBB station in the more middle portion of the drainage (Table 16). With reference to the downstream location, about 80% of the smaller streams demonstrated lower mean macroinvertebrate abundances than the Tongue, but the mean value for the upper station was very close to the 50% median for the region. The Tongue River, therefore, had a higher level of secondary production than several of the creeks in the southern Fort Union region, and these differences were fairly pronounced in a few of the cases, particularly with reference to the Pyramid Butte location on the main river. For example, the mean abundance level of the middle Tongue was approximately four times greater than that in Canyon Creek which is a minor tributary. However, if data from the upper Tongue are also considered along with data from the more productive smaller streams, then the Tongue does not appear to have an excessively high production level in relation to the entire study area. Thus, the secondary waters of the inventory area can be generally classified as having relatively high macroinvertebrate densities on the basis of this mainstem comparison also.

Stream Classification. When the mean macroinvertebrate abundances of each of the stream stations are arranged in a sequence so that the lowest density has a rank of one, the next lowest has a rank of two, and so on, with the highest density having a rank of 35, a series of numbers is developed that shows a rather gradual increase in density levels from one of the ranks to the next highest site. A significant correlation coefficient was obtained between rank and density ($r = 0.88$), and the statistical slope of a graph between these two variables produces a relatively small 724 N/m^2 difference in abundance between any two of the adjacently ranked stations. The major exception to these generally low inter-rank differences in density was found in the distinctively high abundance levels of the Sqrrl and UOtr-O Stations. But otherwise, a separation of the stations into groups on the basis of their mean densities proved to be very difficult because of the gradual transition. However, low, moderate, and high abundance streams could still be recognized along this density gradient, and Table 17 presents a somewhat arbitrary classification system along these lines. This table also contains the stations' density rankings.

Only two obvious patterns of stream density distribution could be recognized in the abundance classes of Table 17: One pertains to the prevalence of the small Yellowstone River tributaries in the low abundance category, while the other deals with the relationships between the total abundances of the streams and their flow characteristics which will be discussed below. Except for the Yellowstone tributaries and the Powder River-Mizpah stations, no distinct differences in density could be identified among the remaining drainage areas that have been delineated in Tables 9 to 14.

In the main, stream size, i.e., discharge as labelled in Tables 1 and 17, does not appear to be a major factor in defining secondary lotic production in the study region since the density levels of the larger perennial waters and that of their smaller counterparts were observed to be scattered throughout the ranked sequence without any obvious aggregations. However, the intermittent streams did show a tendency to be lumped among the lower rankings as is illustrated in Table 17. As a result, the eight intermittent waters provided a mean density of 6,179 N/m^2 in contrast to a higher average of 10,533 N/m^2 for the 27 perennials, and this comparison indicates that the intermittent streams tended to have a lower total macroinvertebrate abundance than the perennial variety. But if a continuous flow happened to be present, then it does not appear that the volume of this discharge had a major effect on the benthic abundance of a station since the small perennials provided an average density 10,950 N/m^2 versus a mean of 9,541 N/m^2 for the larger streams. Apparently other factors apart from the amount of flow *per se* influenced the abundance features of a stream benthos such as stream morphometry (the presence of riffle areas), the occurrence of intermittency as noted earlier, the nature of the stream substrates, and certain of the water quality variables. In addition, the primary production aspects of the streams probably played an important role in defining the macroinvertebrate abundance characteristics of the waters.

Study Area Variability. The streams in the coalfield area demonstrated a fairly wide latitude in their benthic macroinvertebrate abundances, both geographically and on a collection date basis, and this geographic aspect

Table 17. Biological classification and ranking of the project region streams on the basis of the mean total abundances of their macroinvertebrate associations (number of individuals per square meter from natural substrates).

Low Abundance 1,180 to 4,850	Moderate Abundance 5,870 to 9,890	High Abundance 12,070 to 20,280	Very High Abundance 31,510 to 38,120
1. WFArm: si	15. Muddy: sp.	24. LRsb-R: lp	34. UOtr-O: sp
2. Sweeny: sp	16. Davis: si	25. Reserv: sp	35. Sqrrl: sp
3. MRsb-C: lp	17. UHWC-D: sp	26. LOtr-A: sp	
4. Deer: si	18. PR-Mo: mjp	27. LHWC-B: sp	
5. LArm-F: sp	19. Bear: sp	28. Ash: sp	
6. EFHWC: sp	20. URsb-K: mlp	29. TR-PBB: mjp	
7. PR-Mz: mjp	21. TR-ShD: mjp	30. LameDr: sp	
8. Cow-O: sp	22. Bull: sp	31. Beaver: sp	
9. Sarpy: sp	23. Pmpkn: li	32. Cook: si	
10. PrDog: si		33. Indian: mlp	
11. Canyon: sp			
12. Mizpah: li			
13. Youngs: sp			
14. Logging: si			

si--small intermittent; sp--small perennial; lp--large perennial, mjp--major perennial; li--large intermittent; mlp--moderately large perennial.

has been illustrated previously through a comparison of the mean and median density values of the different sampling stations. The high mean/median ratios for many of the sites indicate that a part of the study area variability was due to the obtainment of a few samples that had extremely high abundance levels in relation to the other collections. This variability, in turn, was quite pronounced for the project waters on a sample basis. The minimum-maximum values in Table 16 point to an extreme range that involved an 11 N/m^2 density in a few of the samples to an unusually high density value of 120,555 N/m^2 for one exceptional collection. These minimum-maximum differences were much less distinct in relation to each of the individual stations, but they are still quite pronounced with minimum-maximum averages of 1,642 and 27,857 N/m^2 providing for a more typical 17-fold variation for the entire study area. A high variability component is also reflected in the percent deviation data of Table 16 with percent deviations well above 50% for most of the sites and above 100% for eleven of the stream locations. This statistic averaged 89% for all of the applicable sites.

A review of the total sample density data that are available for each of the stations in Klarich, et al (1980) reveals a general consistency in the inter-sample abundance differences that can be seen at most of the sampling sites. In many cases a few samples were collected with somewhat low densities while one or two of the samples had comparatively high abundance levels; but most of the collections provided numbers that were in fairly close proximity to the station mean. If a high abundance sample is defined as one that has a density in excess of 1.5 times the station mean with low abundance samples having densities at less than 0.3 times

the mean, then 21% of the study area collections can be classified as having high density levels with another 26% falling into the low abundance category. The remaining 53% of the samples would have abundance values that are fairly representative for a particular stretch of stream. These high and low density samples show a seasonal relationship that will be described later. As an added note, the densities of the individual taxa at each of the stations also revealed a marked variation between the samples in correspondence to the differences in total abundance. A range in the vicinity of five to 3,500 N/m^2 was found to be commonplace for some of the more prevalent organisms.

Only a very small part of the variations in total macroinvertebrate abundance can be attributed to differences in the number of samples that were collected from the different sites since a fairly low positive correlation coefficient ($r = 0.33$) was obtained between sample number and percent deviation. This coefficient is statistically insignificant at 5% but significant at 10%. At the 90% level of probability therefore, a slight tendency was shown for inter-sample variability to increase as a larger set of samples was collected. But for the most part, a major portion of the differences in macroinvertebrate abundance with reference to sampling date were probably caused by various _in situ_ factors that were operating in the streams.

Four examples of such instream factors can be listed as follows: (1) the inadvertent collection of samples from relatively sterile or from unusually favorable stream locations on some of the site visits; (2) the collection of samples during different life cycle stages of a macroinvertebrate cohort; (3) the collection of samples before and after an emergence event; and (4) the collection of samples during different seasons of the year. The latter listing is closely related to the second and third items to some extent, although seasonal sampling would also involve different physical and water quality factors such as runoff scouring and temperature changes that are not direct biological manifestations of the organisms. The actuality of seasonal oscillations in the macroinvertebrate abundances of the sampling sites will be illustrated in a later section of this report. For whatever reasons, the streams of the study region describe a highly dynamic ecosystem with widely fluctuating and variable macroinvertebrate associations through time, across space, and from a faunistic-compositional viewpoint.

FAUNAL SIMILARITIES AND DISSIMILARITIES AMONG STATIONS

General Features

Percent similarity (PS) computations between station pairs were completed for the nine intensive sites (Table 1) and for four accessory sites (Indian, Beaver, UOtr-O, and Reserv) that had five or more samples. Since the PS calculations were to be directed to the mean density-PRA values of the dominant taxa at the stations, this restriction was initiated to help insure that the data were fairly representative of a station's actual faunal characteristics as shown through the availability of a larger number of collections. However, such a limitation did not narrow the scope of these analyses to any significant extent because all of the stream types (major and relatively large perennials, variously sized small perennials,

and intermittents) and all of the drainage areas were represented along with all of the important streams of the study region. In addition, a few extra PS determinations were completed from among the remaining stations for illustrative purposes.

The thirteen primary stations involved 78 individual comparisons with an average PS for the 78 pairs of 46.5%. This fairly low, study area PS mean suggests that the streams have a wide variation in their faunal compositions as illustrated in Table 16, and the 46.5% figure is representative of a general background similarity that can be found throughout the inventory region. As a result, any station pairs that have PS values significantly higher than 46.5% (above 60%) might be judged as being somewhat similar, while the station pairs that have values considerably less than 46.5% and in the vicinity of 33% can be graded as being largely dissimilar in terms of their dominant faunal components. In contrast, those station pairs that have intermediate PS levels are most logically viewed as nondistinctive and simply reflective of the overall similarity characteristics of the southern Fort Union region. The relatively low background component that was obtained from this analysis indicates that the study area streams tended to be generally dissimilar from each other faunistically through most of the comparisons. Of the possible station pairs, eighteen were graded as similar, nineteen as significantly dissimilar, and forty-one were graded as nondistinct and coincidental with the low faunal background "noise" that comprises the macroinvertebrate associations of the inventory region waters.

Compositional Differences

The Tongue River at the Pyramid Butte site is quite distinct faunistically for the study region because of the low PS values that were consistently obtained from all of its station comparisons. The TR-PBB site provided an average PS of only 29.8% for the twelve station pairs. If faunal dissimilarity (DS) is defined as DS = 100% - PS, then the middle Tongue demonstrates a marked difference on the order of 70% from the other streams that were examined in this fashion. Thus the Tongue appears to be faunistically unique in relation to most of the inventory waters since none of the remaining stations produced mean PS values that were lower than 50%. This expression of faunal uniqueness coincides with an earlier observation that described the middle river's comparatively broad selection of minor taxa. However, such low PS values might be anticipated for the river with reference to the faunal classification system in Table 16 where the TR-PBB site was classified as an Elmidae stream in contrast to the high densities of midges, caddisflies, and/or black flies that were typically collected from the non-mainstem waters. Not surprisingly, the TR-PBB station showed a fairly high faunal similarity with the upper site on the river (64.2%).

Two other streams (Logging and Cow Creeks) that were not included with the main similarity evaluations can also be classified as Elmidae streams along with the Tongue River even though these creeks were quite different from the Tongue in terms of their flow characteristics (Table 17). But in conjunction with these hydrological discrepancies, the three Elmidae streams did demonstrate separate genera of dominant riffle beetles at the sampling sites (i.e., Microcylloepus at the TR-PBB station, Dubiraphia at the Logging station, Optioservus at the Cow-O station) so that these lotic systems were

still fairly distinct from one another on a faunal basis. Each of the riffle beetle streams provided generally low PS values in relation to each other (16.2% to 31.6%) and in relation to many of the other stations as described for the TR-PBB site.

In addition to nine of the TR-PBB comparisons, ten additional station pairs in the main PS assessments apart from the TR-PBB station also exhibited fairly significant faunal dissimilarities with PS < 33% and with DS > 67%. These station pairs can be listed as follows: URsb-K and UHWC-D (32.7%), Indian and LOtr-A (30.7%), Sqrrl and EFHWC (32.4%), Beaver and EFHWC (27.6%), Beaver and UOtr-O (29.3%), Pmpkn and EFHWC (32.3%), Mizpah and UOtr-O (18.9%), Pmpkn and UOtr-O (21.2%), Reserv and EFHWC (29.6%), and Reserv and UOtr-O (32.9%). As might be expected, each of the members of these pairs had to be placed into a different faunal category than its associate (Table 16) as follows: URsb-K in Chironomidae-Hydropsychidae versus UHWC-D in Simuliidae-Hydropsychidae, Indian in Hydropsychidae-Chironomidae versus LOtr-A in Chironomidae-Simuliidae, and so on to Reserv in Hydropsychidae-*Hyalella*/*Physa* versus EFHWC in Simuliidae-Hydropsychidae. On the basis of these listings, the EFHWC and UOtr-O sites also appear to be fairly distinctive faunistically from several of the other streams in the study region with at least four significantly low PS values and with somewhat low mean PS values of 42.0% and 40.6% respectively. These dissimilarities also point to the occurrence of distinct faunal variations in the coalfield area streams.

Compositional Consonance

In contrast to the obvious faunal dissimilarities of the TR-PBB station from the rest of the project region streams as revealed by the middle river's low mean PS value, none of the remaining primary sampling sites were observed to stand out in an opposite fashion by demonstrating a marked faunal similarity and a high mean PS value with reference to the other twelve streams. The UHWC-D, LHWC-B, LOtr-A, and Indian sites proved to be the most "typical" faunistically with the higher PS numbers, and Bahls (1980) has noted that the LHWC-B location was the most "typical" of the sites in a floristic sense. Nevertheless, the mean faunal PS values of these four streams were still shown to be relatively low, ranging from 52% to 54%, and not extremely different from the study area mean. This feature also suggests that the faunal compositions of the streams tended to be more dissimilar than similar through most of the comparisons. However, eighteen of the individual station pairs did provide high PS values above 60% which indicates a close faunal similarity between any two of these particular sampling sites. These station pairs were typically characterized by one or more of the following linking features: (1) they were in close proximity to each other geographically; (2) they were in the same general drainage area; (3) they were equivalent types of streams hydrologically; and/or (4) they were in a closely similar faunal classification.

The URsb-K and Indian station pair provides an obvious example of a faunal similarity between streams with a PS value of 73.7% that is well above the study area mean, and these two sampling sites were equivalent to each other with respect to items one to three listed above. The Pmpkn and Mizpah sites also demonstrated a faunal consonance with an identical PS reading of 73.7%, and these streams were related because of items three

and four where they are both representative of the large intermittent type of stream in the coalfield area. The Beaver and Reserv stations afford another example of a distinct faunal similarity with a PS value of 73.3%, and both of these streams have been placed into the Hydropsychidae-Hyalella/Physa class on the basis of their macroinvertebrate compositions. The Hyalella/Physa streams like Beaver and Reservation Creeks consistently demonstrated relatively high abundances of the Chironomidae or the Hydropsychidae which is the principle faunal thread of the study region, but these streams were somewhat unique in showing high densities of the Talitridae and Physidae which were not commonly observed in high numbers in the remaining waters. Furthermore, the Hyalella/Physa creeks were generally equivalent hydrologically in being small perennials with a few small intermittents, and they typically contained relatively plush growths of macrophytes and/or macroalgae which have been observed at the Beaver and Reserv stations.

A major portion of the inter-station faunal similarities that were recognized in these assessments were identified among the sampling sites in the Hanging Woman and Otter Creek drainages. Of the ten principle comparisons within the Hanging Woman-Otter group, eight of the pairs demonstrated PS levels above 60%. Such similarities might be anticipated since this particular set of streams afforded a mixture of all of the four linking factors that were listed earlier. Distinct in this regard was the UHWC-D and LHWC-B pair with an extremely high PS of 87.6% and a difference rating (DS) of only 12.4%. These two stations, in turn, were located in close proximity of each other and in the same drainage area (on the same stream), were observed to have generally equivalent hydrological characteristics, and were placed into the same Simuliidae faunal class. Because of these kinds of relationships, the five principle stations within the Hanging Woman-Otter drainages provided a mean PS among themselves of 66.0% in contrast to a mean value of only 39.7% with reference to the outside streams.

A chi-square (X*) evaluation of the Hanging Woman-Otter PS data indicates that the within drainage and without drainage comparisons were significantly different from the study area mean at the 0.5% level (X* = 9.17 with one degree of freedom). These analyses afford a statistical conformation of the faunal variations that have been observed in the project region with the waters that happen to fall into the two Simuliidae categories having statistically significant faunal similarities among themselves while being significantly different statistically from the non-Simuliidae streams. As a further confirmation, the faunal dissimilarities of the TR-PBB station were also shown to be statistically significant of the 2.5% level with X* = 6.04 in this particular case.

The remaining seven sampling site pairs that demonstrated significantly similar faunal compositions can be listed as follows: URsb-K and Sqrrl (76.4%), URsb-K and LOtr-A (60.1%), Indian and Sqrrl (72.9%), Indian and Pmpkn (63.4%), Sqrrl and LOtr-A (64.5%), Beaver and Pmpkn (73.6%), and Beaver and Mizpah (72.6%). On first glance, the members of some of these station pairs appear to show rather disparate features relative to the four linking factors that were listed earlier. However, at least one or two of these factors were found to apply to some extent upon closer examination, and with the faunal similarities of the members,

some environmental equivalencies might be expected for the two associate stations.

Qualitative Comparisons

The PS index is dependent both upon the types of dominant taxa at any two stations and upon the relative abundances of these important organisms, and the quantitative component can have an overriding effect on the magnitude of the index value. In order to judge the faunal similarity characteristics of the sampling sites in the study region entirely on the basis of their complete taxonomic compositions, qualitative similarity index (QS) values were also determined for a select set of station pairs that were chosen to describe the extremes of faunal consonance and dissimilarity as revealed by their PS numbers. For additional contrast, a few station pairs were also included into this QS analysis that provided relatively nondistinct PS values in this regard.

The PS values of the station pairs that were included into the QS assessments ranged from 18.9% to 87.6%, providing a mean PS of 51.2% which is fairly close to the average PS that was obtained for the project region. The corresponding QS numbers of the pairs ranged from -4% to 48% with a mean QS of 22.1%. These QS values were shown to be equivalent to PS expressions varying between 48% and 74.5%, and an average equivalent PS of 61.1% was computed from the QS data. As suggested by a comparison of the PS and the equivalent PS ranges, the QS evaluation acts to reduce the breadth of the similarity/dissimilarity differences in the study region by enhancing the similarity aspects of the generally non-similar streams, as described by the PS assessments, while lowering the similarity features of the more consonant waters. However, the equivalent PS values of the more similar stream stations were lowered much less through the QS evaluations than the increases that were observed for the generally dissimilar locations. For example, the disconsonant Sqrrl:EFHWC pair provided a positive change in similarity of 130% while the largely similar URsb-K:Indian duo afforded a negative change of only 26.7%. As a result, the net effect of the QS assessment was to raise the similarity aspect of the study region since a higher overall PS number was obtained from the mean QS value than from the standard PS analysis.

These QS evaluations indicate that the project area waters are somewhat more similar faunistically on a strictly qualitative basis (about 1.25 times) than they are when a quantitative component is included into the calculations. This is due to the fact that the QS index also considers the numerous and less abundant, common and rare macroinvertebrate taxa, as well as the dominant forms, that are observed throughout the inventory area in varying patterns of distribution. Since all of the station pairs have a fairly large set of these less prevalent taxa that are common to both of the stream reaches, this feature enhances the faunal similarities of the two locations when expressed through a QS value. In contrast, the PS assessment is primarily dependent upon the relative densities of a few dominant taxa that can show pronounced abundance differences among the streams as illustrated in Tables 9 to 14. The QS data, therefore, point to a significantly high qualitative similarity component among the coalfield area streams that is above 60% because of the widespread occurrence of the less dominant forms. Furthermore, the streams express a dissimilarity

component along these same lines of 39%; that is, about 61% of the discrete taxa that were encountered in a "typical" inter-station comparison were identified at both of the sites while 39% were found at only one of the station pairs.

STATION DIVERSITY AND COMMUNITY STRUCTURE

General Descriptions and Interpretations

Taxa Numbers. Table 18 presents the faunal diversity data that were accumulated for the various sampling sites during the course of the project. This table contains a summary of the different Margalef expressions that were computed for the individual station samples and the sampling sites, a listing of the Shannon-Weaver and equitability values that were determined from the mean taxa densities of the stations, and a listing of the minimum-maximum, sample mean, and total number of discrete macroinvertebrate taxa that were obtained from each of the collection sites.

The expected number of total taxa that are listed in Table 18 for each of the locations were estimated by first separating the stations on the basis of their sample numbers (Table 16), by then determining median values from the station taxa numbers in each of these sets, and by finally plotting a graph of these medians versus the number of samples. This graph produced a fairly distinct parabolic-type curve with an asymptote in the vicinity of 42 taxa, and it revealed the following sequential relationship between sample number and total taxa: one sample--ten taxa, two samples--seventeen taxa, three samples--23 taxa, and so on to eight samples--36 taxa and sixteen samples--42 taxa. The expected number of total taxa for each station in relation to the number of samples collected could then be obtained from the graph. This curve further indicates that about 42 discrete taxa at the taxonomic resolution levels of the inventory might be expected in the riffle benthos of a sampling site with approximately 85% of these taxa retrieved from a study area stream after the application of eight Surber collections. With the obtainment of eight additional samples, only six new taxa would be anticipated for the station.

In contrast to the total number of station taxa, much smaller assortments of discrete taxa were collected with each of the individual samples, and between eight and sixteen taxa were obtained in two-thirds of the macroinvertebrate collections. As a result, only one-third of the stream's taxa were retrieved on any given site visit with reference to an average sample. However, the average number of taxa per sample varied to a considerable extent among the stations, ranging from 6.3 to 19.3, and these lower taxa numbers were generally correspondent with a low diversity situation. Therefore, Margalef diversity provided a relatively high and significant (<1%) positive correlation with taxa number ($r = 0.80$ and $r = 0.90$ for M_s and $\overline{M}_s$ respectively), although an insignificant correlation coefficient was obtained between $\overline{M}_s$ and average site abundance ($r = 0.02$). Similar relationships were noted for the Shannon-Weaver index with $r = 0.63$ for taxa numbers and $r = -0.11$ for density. On this basis, the number of taxa proved to be the most important component of diversity with total abundance having no observable effect even though abundance is involved in the Margalef calculations.

Table 18. Diversity characteristics of benthic macroinvertebrate associations collected from natural stream substrates in the southern Fort Union coalfield region of southeastern Montana. Descriptions of the column headings are included in the table footnotes.

Station	Number of Taxa					Margalef Index						
	Samples			Station		Samples				Station		
Symbol	Min	Max	Mean	Tot	Exp	Min	Max	Mean	Med	M_O	SW	e
URsb-K	1	16	11.0	34	41	0.00	3.02	1.62	1.54	1.51	2.40	0.65
MRsb-C	12	20	16.0	28	23	2.47	3.40	3.09	3.39	3.01	3.51	1.03
LRsb-R	--	--	13.0	13	10	--	--	1.71	--	1.71	2.27	0.50
Indian	14	22	17.7	39	33	1.46	3.37	2.55	2.71	2.21	2.57	0.46
Davis	16	22	19.3	31	23	2.40	3.97	3.13	3.02	2.90	1.97	0.27
Muddy	9	18	13.3	28	28	1.38	2.62	1.98	1.95	1.94	2.93	0.81
LameDr	11	20	15.5	31	28	1.20	3.24	2.31	2.41	1.97	2.69	0.58
Tr-ShD	15	19	17.0	34	28	2.39	2.66	2.47	2.42	2.38	3.29	0.82
Ash	9	17	12.7	25	23	1.55	2.18	1.92	2.02	1.62	2.30	0.53
Youngs	11	14	12.5	21	17	1.54	2.43	1.99	1.99	1.90	2.19	0.49
TR-PBB	8	26	17.3	43	40	1.24	3.37	2.34	2.36	2.24	3.56	0.98
Sqrrl	8	17	13.1	33	37	1.04	2.39	1.64	1.67	1.48	2.01	0.41
Deer	8	13	10.7	21	23	1.21	2.75	2.13	2.42	1.89	2.52	0.74
Canyon	13	20	16.0	25	23	1.94	3.38	2.59	2.45	2.55	2.96	0.68
PrDog	12	13	12.5	16	17	1.92	2.07	2.00	2.00	2.00	3.05	0.94
Bull	9	14	11.5	15	17	1.21	1.89	1.55	1.55	1.55	2.23	0.55
Cook	6	19	13.3	29	23	0.86	2.68	1.74	1.69	1.66	1.79	0.34
Logging	15	18	16.7	31	23	2.12	3.74	2.80	2.55	2.56	2.71	0.54
Beaver	10	17	13.2	29	31	1.41	2.28	1.70	1.67	1.65	1.98	0.39
UHWC-D	6	16	10.7	33	41	0.92	2.96	1.67	1.42	1.51	2.11	0.53
LHWC-B	4	16	9.8	40	42	0.55	3.58	1.38	1.12	1.22	1.99	0.53
EFHWC	3	21	12.4	41	39	1.24	3.53	2.31	2.18	2.15	3.06	0.95
Bear	12	15	13.3	24	23	1.72	2.29	2.04	2.10	1.88	2.60	0.63
UOtr-O	9	17	13.7	35	35	1.03	2.43	1.80	1.76	1.59	1.79	0.33
Cow-O	11	16	13.5	20	17	1.68	2.74	2.21	2.21	2.18	2.88	0.77
LOtr-A	3	19	10.9	40	41	0.91	3.81	1.62	1.49	1.40	2.24	0.58
Pmpkn	3	13	8.1	22	36	0.81	2.55	1.63	1.46	1.04	1.43	0.41
Mizpah	3	10	6.3	21	36	0.67	3.08	1.56	1.30	0.89	1.90	0.78
WFArm	4	9	6.5	11	17	0.74	1.57	1.16	1.16	1.17	1.60	0.59
LArm-F	1	11	6.3	14	23	0.00	1.82	0.96	1.05	1.02	2.58	1.30
Sweeny	3	12	7.5	15	28	0.60	1.92	1.31	1.36	1.31	2.58	1.09
Reserv	8	17	13.4	31	31	1.44	2.73	1.98	1.67	1.75	2.45	0.56
Sarpy	2	13	9.0	19	28	0.35	1.96	1.38	1.61	1.39	1.79	0.50
PR-Mo	--	--	10.0	10	10	--	--	1.39	--	1.39	1.68	0.41
PR-Mz	--	--	4.0	4	10	--	--	0.53	--	0.53	0.23	0.07

The minimum (min), maximum (max), and mean number of discrete taxa collected with a station's samples; the total (tot) number of discrete taxa obtained from a station for all of its samples and the number of taxa expected (exp) for a station on the basis of the total number of samples collected. The minimum (min) and maximum (max) Margalef index (M_s) values obtained from a station's samples, and the calculated mean ($\bar{M}_s$) and median Margalef values and the overall Margalef index (M_O). The Shannon-Weaver (SW) diversity of a station and the associated equitability (e) number.

Margalef Index. As indicated in Table 18, a fairly wide variation in Margalef diversity was obtained from the single samples collected from the study area streams. These M_s values ranged from a low of zero in a few samples with the collection of only one taxa on a site visit to high values in excess of 3.00 and approaching 4.00 for those cases where station samples were found to contain between 29 and 26 discrete macroinvertebrate taxa. Wide variations in M_s were also found at several of the individual sampling sites, particularly when a large number of samples were collected (e.g., URsb-K and LHWC-B), but for some of the stations, the minimum-maximum differences in M_s were not particularly pronounced (e.g., TR-ShD and PrDog). A part of this variability in station diversity could be reflective of the general patchiness of the macroinvertebrate populations on the stream bottom, or they could be related to inadvertent alterations in sampling techniques. But since seasonal sampling was conducted during the project, a portionof the variability could be due to changes in the environmental conditions of the streams from one sampling date to the next collection period.

The Margalef diversity values ($\overline{M}_s$, median, and M_o) demonstrated a much narrower span of differences on a station basis than on a sample basis, ranging from a low 0.53 for the PR-M_z site to a high in the vicinity of 3.00 for the MRsb-C and Davis locations. This range provides a six-fold variation in diversity for the study region, and these summary statistics are probably most indicative of the actual diversity characteristics of the streams. These predictions, of course, are much more valid with the collection of a larger number samples, and as a result, the diversity estimates of the intensive sites are probably most secure in this regard. However, these nine intensive stations also revealed a wide variation in M_o diversity levels, and these differences appear to be a characteristic feature of the study region with some of the streams exhibiting a higher environmental stress component than others. This stress factor was relatively low in the Tongue River in view of the river's relatively high diversity value (M_o = 2.24), and it was higher in many of the smaller coalfield area streams with their lower diversity levels. About 85% of the sampling stations had M_o values less than 2.24, and another 25% of the sites had M_o's markedly less than that of the Tongue and less than 1.40. Thus a few of the streams demonstrated a fairly significant stress component that requires further consideration in terms of their salinity levels.

For the most part, the three station Margalef expressions in Table 18 provide closely similar predictive numbers concerning the biological health of a stream. For example, the mean/median M_s ratios for most of the sampling sites were generally similar and very close to unity with an average ratio of 1.01, and this feature indicates that the variations in station diversity were generally equally distributed both above and below the central point of a data array without the collection of distinctly high or low outlier samples. Therefore, the diversity variations that are evident at the stations appear to be largely random in character without the occurrence of any definite trends. Furthermore, although the M_o value of a station was typically less than its $\overline{M}_s$ number with an average $M_o/\overline{M}_s$ ratio of 1.09, this discrepancy was relatively small and less than 12% for most of the sites. The obtainment of an $M_o/\overline{M}_s$ ratio that is less than one simply points to the collection of a few samples

at a site with comparatively high or low numbers of total organisms, and and the general occurrence of this event during the field work is aptly illustrated in Table 16.

Shannon-Weaver Index and Equitability. As predicted previously, the the Shannon-Weaver (SW) diversities were found to be typically higher than the overall station Margalef values for all but two of the sampling sites, and the SW provided for a wider, 15.5-fold range of difference (0.23 to 3.56) between the station extremes than the Margalef. Equitability also afforded a broad, 18.6-fold range of values among the stations with a mean equitability for the study region of 0.62. The mean SW for the project sampling sites was calculated at 2.34, and this mean is 1.34-times higher than the overall Margalef for the stations of 1.74. This SW/M_o ratio is fairly similar to the 1.51 value that was calculated for this ratio from the theoretical sets of data in Table 5 for the variable or broken stick model. Since a significant correlation between SW and M_o was obtained from this theoretical data, a similar result was anticipated from the actual field data of the inventory, and a positive coefficient of $r = 0.72$ was computed for the SW and M_o pairs in Table 18 that is statistically significant at less than 1%. The Margalef expressions, thereby, appear to be valid and adequate estimators of the SW index in the context of this particular study. Furthermore, equitability (e) and SW diversity were found to be positively correlated to a significant extent with $r = 0.75$ in this particular instance. Therefore, M_o, SW, and e should provide generally similar predictions concerning the biological health of the streams, and all of these indices point to significant differences among the streams with respect to the diversity characteristics of their benthic macroinvertebrate associations.

Like the case for the Margalef, the Tongue River also provided distinctly high SW and e numbers with almost all of the smaller streams showing a lower magnitude of these two biotic variables. Of these smaller systems, approximately one-third of the sampling sites produced SW values below 2.00, and one-third had equitabilities equal to or below 0.50. Another one-fourth had e values between 0.50 and 0.60 so that about 60% of the stations produced equitabilities that fell below the 0.6 to 0.8 range that is common in most biotic systems (Weber, 1973); about 20% had e levels well above this range. Thus, the SW and e indices point to the occurrence of some degree of environmental stress among the non-mainstem streams in contrast to the Tongue River which appears to be representative of a generally unstressed water in the region with a healthy benthic biota on the basis of these analyses. That is, both the TR-PBB and the TR-ShD sites have SW values that fall into the SW > 3.00, Class A category that is descriptive of unstressed systems (Wilhm, 1970) as described previously. The relatively high equitabilities of the two Tongue River sites act to confirm this interpretation. Although some of the smaller streams would also fall into a Class A group, many would have to be given a B, C, or D designation because of their low diversity characteristics. These lower diversities, in turn, are reflected in the mean SW and M_o values for the entire project region since both of these averages would place the waters of the area into the Class B category on an areawide basis which is indicative of a fairly mild level of environmental stress. But a great deal of variability is evident among the streams in this regard on an individual

site basis as will be illustrated later.

Stream Classification. As indicated in Table 18, the total number of taxa actually collected from a station and the expected number of macroinvertebrate taxa did not closely coincide at several of the stream locations with some of the waters appearing to be somewhat depaupered faunistically in relation to a study region norm. Therefore, the relationships between the expected and the total or observed taxa numbers in Table 18 might be viewed as another expression of biotic diversity where a low observed/expected ratio would be generally anticipated for those sites that had low Margalef and SW index values. Of the stations listed in the table, 34% had observed/expected ratios significantly less than one and below 0.93, averaging 0.70, and these same stations also demonstrated low M_o and SW values that averaged 1.27 and 1.87 in contrast to the higher study area means for these indices (1.74 and 2.34). Other delineations of this kind are presented in Table 19, and a high correlation coefficient (r = 0.82) was obtained between the observed/expected ratios and diversity that was significant at less than 1%. Table 19 also presents a classification of the study area streams as low, moderate or typical, and high diversity waters on the basis of taxa richness as defined by the observed/expected ratios, and the sampling stations are split rather evenly among the three groups. Although there is some overlap in the M_o and SW values, distinct diversity differences are evident among the classes that are statistically significant as shown by a completely random, one-way ANOVA with F^2_{32} = 19.75.

Although marked differences in macroinvertebrate diversity are evident among the study area streams, most of these variations could not be definitely related to the faunal compositional (Table 16), hydrological (Tables 1 and 17), or abundance (Table 17) characteristics of the sampling sites; that is, no definite aggregations of stations with reference to these three features could be recognized in the diversity classes of Table 19. In addition, most of the mean diversity differences that could be identified between the categories of the hydrological and abundance groupings were observed to be quite small, and no consistent trends of diversity change could be found along any of the gradients.

In terms of stream hydrology, the larger perennials tended to have slightly higher diversities (mean M_o = 1.87) than the smaller perennials (mean M_o's between 1.68 and 1.76), and the continuously flowing streams tended to have slightly higher diversities (mean SW's between 2.32 and 2.46) than the intermittent waters (mean SW = 2.2). In terms of abundance, the stations with the lower total densities tended to have slightly higher diversities (mean M_o = 1.82) than the sites with the higher abundance levels (mean M_o's near 1.53). But again, numerous inconsistencies in these comparisons became evident between the indices and among the individual categories, and the relatively small differences that were identified could not be shown to be statistically significant at any acceptable level of confidence. As a result, other factors besides stream size, flow duration, and macroinvertebrate abundance must be operating in the coalfield area streams to cause most of the diversity variations that can be observed in these waters.

In terms of the faunal classifications in Table 16, the Elmidae cate-

Table 19. Biological classification of the study area streams on the basis of their taxa richness and the natural substrate diversity characteristics of their benthic macroinvertebrate associations.

Parameter	Taxa Richness-Diversity Class Characteristics: Low Category	Moderate Category	High Category
Station Number	12	10	13
Tot/Exp Range*	0.40 to 0.92	0.92 to 1.07	1.08 to 1.35
Margalef Range	0.53 to 1.82	1.22 to 2.15	1.62 to 3.01
SW Range#	0.23 to 2.58	1.68 to 3.06	1.79 to 3.56
Tot/Exp Mean*	0.70	0.99	1.20
Margalef Mean	1.27	1.70	2.22
SW Mean#	1.87	2.37	2.67

Taxa Richness-Diversity Class and Sampling Stations: Low Category	Moderate Category	High Category
URsb-K	Muddy	MRsb-C
Sqrrl	PrDog	LRsb-R
Deer	Beaver	Indian
Bull	LHWC-B	Davis
UHWC-D	EFHWC	LameDr
Pmpkn	Bear	TR-ShD
Mizpah	UOtr-O	Ash
WFArm	LOtr-A	Youngs
LArm-F	Reserv	TR-PBB
Sweeny	PR-Mo	Canyon
Sarpy		Cook
PR-Mz		Logging
		Cow-O

*The Tot/Exp expression denotes the ratio between the total number of discrete taxa identified at a station and the number of taxa expected with respect to the number of samples collected.

#The SW expression denotes the Shannon-Weaver diversity index values.

gory provided noticeably higher diversities (mean M_o = 2.33) while the Chironomidae/Simuliidae class demonstrated somewhat lower M_o values (mean M_o = 1.49) than the other five compositional groups (mean M_o's between 1.60 and 1.84). In general, streams that revealed high levels of the midges typically showed lower diversities (mean M_o = 1.63) than streams where these same organisms were much less prevalent (mean M_o = 1.93). But in the main, most of the diversity discrepancies that were found in relation to the differences in faunal dominance were observed to be largely nondistinct and insignificant statistically.

Indications of Environmental Stress and Biological Stream Quality

Initial Setting. For the reasons described earlier, the diversity expression of an aquatic macroinvertebrate association can be used as a tool by which to judge the occurrence of environmental stress in a lotic system, and to some degree, the magnitude of an association's diversity index provies some insight into the extent of the stress. In the same vein, diversity can be used as a means for evaluating the biological health of a stream. Two extremes of such diversity interpretations become evident in the data of this inventory (Table 18) with the Tongue River, a major perennial, providing an obvious example of an unstressed stream with high diversities and an excellent biological quality, while the Powder River, another major perennial, affords a prime example of the opposite pole. In the case of the Powder, the river's distinctly low M_o, SW, and e numbers, particularly at its Mizpah site, point to a high degree of environmental stress and a low level of biological health. The high turbidities and the high suspended sediment concentrations that characterize the Powder River appear to be the primary stress components of this particular system.

Between the Tongue and Powder River extremes, some of the smaller project region streams also provided diversity levels that are suggestive of some amount of environmental stress with an accompanying reduction in biological quality, but at the same time, some of these waters afforded diversities that are most indicative of an excellent biological health without the presence of any pronounced stress factors. Numerous environmental parameters besides turbidity and suspended sediment probably account in differing degrees for the variations in diversity that have been noted for the southern Fort Union streams, and salinity appears to be one of the more likely of the candidates. The potential effect of salinity on the benthic macroinvertebrate associations of the inventory creeks and rivers will be illustrated later in this report. However, abundance, stream flow and size, and faunal composition do not appear to have a major influence on the association's diversity characteristics, and this is also true in relation in the intermittent nature of some of the drainages.

Stream Classification. General reference criteria are available in the literature that outline the diversity levels that are typical for unstressed, moderately stressed, and severely stressed aquatic systems, and these criteria have been presented in a previous section of this report in terms of the Class A, B, C, and D categories that were developed for the Margalef and Shannon-Weaver indices. This mode of organization is further summarized in Table 20, and this table also contains a classification of the study area streams and sampling sites with reference to these four stress

Table 20. Natural substrate diversity classification of the study area streams on the basis of the biological quality of their benthic macroinvertebrate associations and the potential occurrence of environmental stress.

Diversity Class:	Class A	Class B	Class C	Class D
Typical M_o Range*:	>2.00	1.35 to 2.00	0.67 to 1.35	<0.67
Typical SW Range*:	>3.00	2.00 to 3.00	1.00 to 2.00	<1.00
Stress Aspect:	Unstressed	Mild	Moderate	Severe
Biotic Quality:	Excellent	Good	Fair	Poor
Most Distinctive	MRsb-C	Loggng#	Beaver#	PR-Mz
Station in Class:		LameDr		
.	TR-PBB	Indian#	LHWC-B	
.		Bear		
.	TR-ShD		Davis#	
.		Deer		
.		Reserv	Cook#	
.	Canyon#	URsb-K		
.		LRsb-R	UOtr-O#	
to				
.	FFHWC	Ash	Mizpah	
.		Youngs		
.		LOtr-A	Sarpy#	
.	PrDog	Bull		
.			PR-Mo#	
.		UHWC-D		
.	Cow-O#	Sqrrl	WFArm	
Least Distinctive		Sweeny#		
Station in Class:	Muddy#	LArm-F#	Pmpkn	
Station Number:	8	16	10	1
Observed M_o Range*:	1.94 to 3.01	1.02 to 2.56	0.89 to 2.90	0.53
Observed M_o Mean*:	2.31	1.70	1.49	0.53
Observed SW Range*:	2.88 to 3.56	2.01 to 2.71	1.43 to 1.99	0.23
Observed SW Mean*:	3.16	2.40	1.79	0.23
Observed e Range*:	0.68 to 1.03	0.41 to 1.30	0.27 to 0.78	0.07
Observed e Mean*:	0.87	0.63	0.46	0.07

*M_o, SW, and e denote the overall Margalef, the Shannon-Weaver, and the equitability indices.

#Denotes a discrepancy between indices concerning the placement of a sampling station in a diversity class.

categories.

As indicated by the listings in Table 20, and as suggested earlier, the Tongue River falls into the unstressed category that is indicative of an excellent biological health (Class A), while the Powder River at its Mizpah site falls into the extremely stressed category which is demonstrative of a poor biological quality (Class D). However, none of the remaining stream stations, including the PR-Mo site, could be placed into the Class D group, although the diversities of ten of the stream locations like the upper Powder were suggestive of a moderate stress situation with only a fair biological rating. A large number of the streams (46%) including two of the Rosebud Creek stations are found in the Class B listing which is suggestive of a relatively mild level of environmental stress and a generally healthy or "good" aquatic biota, and five of the creeks plus one of the Rosebud locations in addition to the Tongue River can be graded as unstressed systems with an excellent biological health on the basis of their diversity characteristics. To some extent, the smaller perennials and the intermittents tend to lean towards the C category while the larger perennials tend to be most commonly relegated towards the A grouping. However, several exceptions can be found to this general observation, and the Powder River and Prairie Dog Creek provide obvious examples.

The different stress and biological ratings of the streams in Table 20 are most secure for the intensive sites and for the few accessory stations where a fairly large number of samples had been collected. For those sampling sites with only a few macroinvertebrate collections, the classifications produced in this inventory are best viewed as first-cut estimates since additional data could revise these preliminary judgements.

With reference to these stream classifications, the Margalef and SW indices made similar predictions for two-thirds of the stations. Of the discrepancies between the two indices that are noted in Table 20, the Margalef demonstrated a greater proclivity for placing a site into a more favorable category than the SW where the Margalef rated a stream more favorably than the SW in 83% of the cases where the two indices did not agree. As a result, the Margalef graded 29% of the streams as Class A while the SW placed only 14% of the stations into this category. In an opposite fashion, the SW rated 31% of the streams as Class C while the Margalef placed only 20% of the sites into this category. Because of these discrepancies, all three of the indices were used in tandem to develop the site classifications in Table 20. In most cases, the SW prediction received preference over the Margalef unless the differences between the indices were quite pronounced, and in these instances, equitability was employed as the primary judgemental criteria. Equitability was also used to "break the tie" in those cases where the Margalef and SW index values were descriptive of a closely borderline situation between any two of the categories. Because of the occurrence of this latter feature, the stations are arranged in Table 20 so that the most securely placed of the sites in any of the classes with their higher diversity levels are located near the top of a listing while the sites that are more tenuous in their class placements with their lower diversity characteristics are located nearer the bottom of a column.

Structural Aspects

Index Relationships. The structural characteristics of the benthic macroinvertebrate communities in the project area streams are described to some extent by the relationships between the SW and Margalef indices that were calculated for the many sampling sites. In the first place, and ignoring the few obvious exceptions, the magnitudes of the indices themselves typically point to fairly diverse macroinvertebrate associations with a fair degree of taxa richness relative to the total abundance features of the streams. Secondly, the high correlation coefficient between the stations' M_o and SW values indicate that most of the associations did not possess an unequal type of distribution of taxa densities across the macroinvertebrate groups, and as a result, most of the communities were not overly dominated by any one of the taxa. Thirdly, the SW/M_o ratios of the sites were generally greater than one which also negates the wide ocurrence of unequal distributions, and since the mean SW/M_o ratio of the sites (SW/M_o = 1.34) was bracketed within the 1.2 to 1.6 SW/M_o range, most of the sites appear to have a variable distribution of macroinvertebrate individuals among the station taxa that is best described by the broken stick model of MacArthur (1957) (see Table 5). Furthermore, most of the individual sites also had SW/M_o ratios within this 1.2 to 1.6 range, or at least above one, and this also points to the general commonness of the broken stick kind of distribution among the different stations. But since the correlation coefficient between M_o and SW was somewhat less than the 0.92 value for r that was predicted from the variably distributed and theoretical set of data in Table 5, some exceptions to the broken stick model were anticipated for the study region.

Four obvious exceptions to a variable distribution are evident in Table 20 as follows: two stations showing SW/M_o ratios significantly less than one (the Davis and PR-Mz sites with SW/M_o values of 0.63 and 0.43), and two stations showing SW/M_o ratios somewhat greater than 1.90 (the LArm-F and Sweeney sites with SW/M_o values of 2.52 and 1.96). The PR-Mz, LArm-F, and Sweeney locations also provided a relatively low number of taxa in comparison to what was observed at some of the other stations for the same number of collections. In essense, the Davis and PR-Mz sites afford study area examples of the unequal type of individual distribution as illustrated in Tables 9 and 14 with an excessive dominance of the Chironomidae in the Davis case and with an excessive dominance of *Cheumatopsyche* in the PR-Mz case. In contrast, the LArm-F and Sweeney sites afford study area examples of a more equal distribution of individuals as illustrated in Table 13, and most of the remaining streams afford examples of the variable form. In addition, the unequally distributed stations demonstrated relatively low equitability values (0.07 and 0.27) in conjunction with their low SW/M_o ratios while the more equally distributed streams revealed relatively high equitabilities (1.30 and 0.90) in conjunction with their high SW/M_o ratios. Such a relationship between SW/M_o and e might be expected since these two variables were observed to be significantly correlated with r = 0.74. Therefore, the SW/M_o expression can be viewed as another indication of station equitability with the higher SW/M_o numbers suggestive of a more equitable distribution of individuals among the station taxa.

Quantitative Characterizations. The general structure of the benthic macroinvertebrate associations in the study area streams is illustrated in Table 21 by the "typical" case or the all-station means that are based on the percent relative abundance (PRA) data from all of the sampling sites. The means PRA values listed in Table 21 are dependent only upon the abundance rankings of the stations, and since they are not dependent upon the particular kind of taxa, each of the ranks is actually representative of several different macroinvertebrate groups. A graph of these ranks versus the ranks' mean PRA's as calculated across the identically ranked taxa produces a hyperbolic-type of curve with a relatively high negative slope between ranks one and two, with moderate negative slopes between ranks two and five, with slight negative slopes between ranks five and eight, and with extremely small negative slopes through the remainder of the graph. Thus the change in PRA between adjacent ranks is most distinctive closer to the y-axis and least pronounced with reference to the larger rank numbers. As a result, about seven-eighths of the macroinvertebrate abundance at a stream location was typically provided by only four of the most abundant taxa as shown by the cumulative summary. If the common taxa are also considered, the top twelve ranked organisms accounted for nearly 100% of this abundance with the less common or rare taxa that have ranks greater than twelve making largely insignificant contributions to total station density.

Since about forty-two discrete macroinvertebrate taxa were typically obtained from a station when an adequate number of samples were collected, at least twenty-five of these taxa provided negligible PRA levels. With the collection of one sample from a stream location, around twelve of the forty-two taxa were obtained, and these single samples generally contained numerous individuals of the abundant and very abundant taxa, a set of the common taxa, and a few representatives of the more rare forms. The collection of a second sample typically produced the same abundant and very abundant organisms along with a selection of common taxa that might have had a somewhat different composition from the first sample because of occurrence of a few new organisms. Some of the rarer organisms were also commonly obtained on the subsequent visits to a sampling site, and a portion of these rare taxa were often different from the low abundance macroinvertebrates that were secured on the initial field trip. However, the identification of new taxa gradually declined as more collections were made from a stream. Following the collection of several samples from a site, the overall community structure features of a station began to emerge as described in Tables 9 to 14 and as summarized in Table 21.

As a general observation on the stream's community structure, the macroinvertebrate associations in the study region typically contained two to five abundant and very abundant organisms that were found in most of the station samples and at high PRA levels, a set of around ten common and very common taxa that were identified in a fraction of the collections and at moderate abundance levels, and a fairly large number of small density or rare macroinvertebrates that were recognized in only a few of the samples. The particular taxon that happened to occupy any one of the PRA ranks of a station was dependent upon the specific faunal composition of a benthos, and these compositions were prescribed by the environmental conditions of the streams. Furthermore, the compositional and structural patterns of the individual macroinvertebrate associations demonstrated some oscillations

Table 21. Structural characteristics of the benthic macroinvertebrate associations collected from natural stream substrates in the southern Fort Union region.

All-Station Means			High-Dominance Stations(1)			Low-Dominance Stations(2)		
Taxa Rank (3)	Rank PRA (4)	Cum. PRA (5)	Taxa Rank (3)	Rank PRA (4)	Cum. PRA (5)	Taxa Rank (3)	Rank PRA (4)	Cum. PRA (5)
1.	45.2	45.2	1.	65.9	65.9	1.	24.0	24.0
2.	22.1	67.3	2.	16.8	82.7	2.	19.1	43.1
3.	13.6	80.9	3.	7.8	90.5	3.	15.6	58.7
4.	6.8	87.7	4.	2.8	93.3	4.	12.5	71.2
5.	3.5	91.2	5.	1.7	95.0	5.	7.2	78.4
6.	2.5	93.7	6.	1.1	96.1	6.	4.6	83.0
7.	1.7	95.4	7.	0.9	97.0	7.	3.2	86.2
8.	1.2	96.6	8.	0.6	97.6	8.	1.9	88.1
9.	1.0	97.6	9.	0.5	98.1	9.	1.7	89.8
10.	0.8	98.4	10.	0.5	98.6	10.	1.2	91.0
11.	0.7	99.1	11.	0.4	99.0	11.	0.9	91.9
12.	0.6	99.7	12.	0.3	99.3	12.	0.8	92.7
13.	<0.6	>99.7	13.	<0.3	>99.3	13.	<0.8	>92.7
a42.	<0.01	100.0	a42.	<0.01	100.0	a42.	<0.01	100.0

(1) Calculations were made from a set of five stations with a highly dominant taxa.

(2) Calculations were made from a set of five stations with a much less pronounced, single-taxa dominance.

(3) Rankings were based on the percent relative abundance (PRA) values of the station taxa with the highest station PRA receiving a rank of one. The mean PRA's of only the twelve top ranks are presented.

(4) The mean PRA of a rank was determined by averaging across the stations' taxa with PRA's having the same ranking.

(5) Cumulative PRA.

(a) Forty-two discrete taxa were typically collected from a station with an adequate number of samples.

through time depending upon the life cycle attributes of the particular organisms and the seasonal characteristics of the drainages. The actuality of such changes are revealed in the data report (Klarich, et al, 1980) by the occurrence of inter-sample differences in taxa abundance at each of the stations, but no attempt has been made to elucidate these specific variations in this present analysis. The information that is presented in Table 21, therefore, provides only an overall assessment of community structure in the project region. The overall structural picture that was ultimately developed for an association is most concrete and well-defined when a large number of samples were made available for a stream location, and as a result, these pictures are much more clear for the intensive than for the accessory sites.

The non-collection of a station taxa in a particular sample does not imply that the organism was totally absent from the stream on that particular collection date, but rather, that the macroinvertebrate was not particularly abundant in the benthos at that time, or that the organism was in a minute cohort life stage so that it was simply missed by the field collection or laboratory analytical procedures. However, the number of misses that are recorded through a large number of samples is related to the general rarity of a taxa in a certain stream habitat, and this feature is ultimately reflected in the low mean station density data of these organisms and their low PRA rankings. Furthermore, if the taxa was not identified at a sampling site through a large number of collections, then there is a fair likelihood that the macroinvertebrate was not present at the station in the habitat being sampled, and the probability of this absence increases in proportion to the number of samples that are collected. On this basis therefore, some of the taxa identified during the study did not appear to be present in the benthos of all of the sampling locations with these same organisms showing somewhat restricted distributions in the project region. But many of the other organisms such as the Cironomidae and the Hydropsychidae did possess a highly ubiquitous character in being found in all or almost all of the streams.

Two fairly distinct variations to the basic structural pattern that is described by the all-station mean PRA's became evident in the inventory data, and these variations are also presented in Table 21. In one of these, the dominance of a single taxa was much more pronounced than in the overall mean expression producing a much more abrupt curve between rank and PRA with a higher negative slope between ranks one and two. Stream stations falling into this class are Davis, Cook, Pmpkn, WFArm, and Sarpy, and the PR-Mz site was most markedly dominated by a single taxa (Table 14). In contrast to this high-dominance case, the other variation produced a much more gradual hyperbolic-type curve that is more linear in nature with less distinct negative slopes among the upper ranks and with the PRA's spread more evenly through the twelve rankings. Examples of the low dominance streams are the Tongue River and Prairie Dog, Muddy, and lower Armells Creeks. But in spite of these differences, the general descriptions that have been directed to the more typical case can still be applied to these two modifications.

Model Comparisons. The quantitative features of MacArthur's (1957) community structure model are illustrated by Whittaker (1970), and by comparison, the low-dominance variation presented in Table 21 makes the closest approach of the three options to a broken stick form of distribution of taxa densities among the different macroinvertebrate groups. The high-dominance

data, in contrast, has a greater similarity to the geometric series described by Whittaker which is characteristic of biotic communities that are commonly found in relatively severe environments. In conjunction with this observation, the six study area streams that tend to fit a geometric pattern with a highly dominant taxa also afforded comparatively low SW diversity values that averaged 1.47 for the six macroinvertebrate associations, and these low diversities are also suggestive of some degree of environmental stress. However, the five streams that most closely copied the broken stick distribution provided an average diversity of 3.08 which is indicative of the unstressed systems that generally coincide with the MacArthur model.

In contrast to the high-dominance and low-dominance options, the benthic faunal associations in the inventory waters that are structurally described by the all-station means in Table 31 provide somewhat of a hybrid between the broken stick distribution and a log normal distribution that is characteristic of taxa rich communities that have a "few very important species, and few very rare species, and many species of intermediate importance values . . . . (Whittaker, 1970)." This typical case tends to be somewhat similar to the broken stick model through the upper PRA ranks, but it tends to be more similar to the log normal distribution through the lower PRA values. The low-dominance distribution in Table 21 is also generally similar to the log normal pattern through the lower ranks because of the large number of low abundance taxa. But in all instances, the community structures of the streams provide only a few highly abundant taxa in the upper ranks with an increasing number of taxa through the lower ranks represented by fewer and fewer numbers of individuals, and this general organization is descriptive of most healthy aquatic systems (Weber, 1973).

SEASONAL VARIATIONS AND YEAR-TO-YEAR COMPARISONS

Intra-Year or Monthly Differences

Assessment Approach. Distinct inter-sample discrepances in macroinvertebrate taxa abundance, total station abundance, and station diversity have been noted for the various stream sampling sites in the southern Fort Union region. Although the variations in individual taxa density have not been extensively analyzed, a review of the single-sample total abundance and diversity data did suggest that some of the differences of this kind had a definite seasonal or monthly relationship that was much more distinct with reference to the abundance information than with reference to sample diversity. Two approaches were used to quantify and illustrate these monthly variations.

In the first of the two evaluations, the percentage of low and high abundance samples that were collected from the stations during each of the ten field months (minus December and January) were determined on the basis of the definition presented earlier; i.e., the high abundance samples had densities greater than 1.5 times the station mean while the low abundance samples had densities less than 0.3 times the station mean. In the second approach, a total percent relative abundance value was calculated for each of the samples from those stations where collections had been made during four or more separate months, and these conversions were completed by divid-

ing each of the individual sample densities by the maximum sample density that was recorded for the station. These converted data from all of the appropriate stations were then segregated by month, and an average total percent relative abundance was then computed for each of the ten months. Thus, if the maximum total abundance that was observed from each of the stations had happened to be obtained during the same month, then the relative abundance mean for that month would be closely equal to 100%, and the lower numbers would be indicative of reduced densities relative to the maximum abundances that were noted for the different sampling sites. Such conversions were necessary for making the seasonal-monthly evaluations because of the distinct differences in macroinvertebrate abundances among the stations, and the maximum station density was chosen as the reference value because it provides for an absolute endpoint number.

Similar analyses were directed to the inventory's diversity data. This involved a determination of the percentage of high and low diversity samples by month and the calculation of mean monthly percent relative diversity values that were based on a station maximum. The results of these abundance and diversity assessments are presented in Table 22. Since the monthly mean percent relative abundance and diversity values in this table are well below 100%, this points to the occurrence of some differences among the stations as to which of the field months produced the maximum abundance and the highest diversity samples. Nonetheless, distinctive monthly trends do emerge from these refined data, and such trends are most pronounced in relation to the total abundance assessments.

Data Evaluations. As indicated by the data summaries in Table 22, the total abundance levels of the macroinvertebrate associations in the study area streams definitely demonstrated a seasonal fluctuation since obvious density differences became evident among the ten field months with these abundance differences showing a distinct pattern. In the first place, much higher percentages of low abundance samples were collected during the high runoff, spring months of April, May, and June than during the warm weather, low flow season, and no low abundance samples were collected during the cold weather months. In an opposite fashion, higher percentages of the high abundance samples were obtained during the low flow, summer and fall months of August to November with no or only low percentages of high density samples collected during the late winter and during the runoff period. July also produced a low percentage of high abundance samples.

These seasonal differences in the collection of low and high abundance samples are also reflected in the monthly mean percent relative abundance data in Table 22 where an abundance peak was obtained from the streams for the warm weather, low flow months of August and September. A second peak was also observed during the late fall period (November) which coincided with a rather distinct algal bloom that was noted for the stream during this same month. From this second peak, abundance levels then gradually declined to their lowest level in April, and they were gradually built-up again through the subsequent months to the midsummer highs. This cycle produced a consistent 4.7-fold overall change in total macroinvertebrate abundance in the study area streams from the spring low to the two summer and fall peaks.

Although seasonally-related abundance variations became quite obvious

Table 22. Seasonal variations in the total abundance and diversity characteristics of macroinvertebrate associations collected from natural stream substrates in the southern Fort Union study region.

Monthly Percentages of High Total Abundance Macroinvertebrate Samples

February	March	April	May	June	July	August	September	October	November
0.0	0.0	0.0	0.0	3.3	9.3	43.5	38.5	22.2	33.3

Monthly Percentages of Low Total Abundance Macroinvertebrate Samples

February	March	April	May	June	July	August	September	October	November
0.0	25.0	50.0	56.3	56.7	27.9	13.0	11.5	0.0	0.0

Mean Percent Relative Total Abundances of Macroinvertebrates by Month

February	March	April	May	June	July	August	September	October	November
28.7	20.8	10.0	17.0	18.2	21.7	46.3	46.1	29.3	46.8

Monthly Percentages of High Diversity Macroinvertebrate Samples

February	March	April	May	June	July	August	September	October	November
0.0	25.0	0.0	6.7	30.0	23.7	29.3	16.0	11.1	27.3

Monthly Percentages of Low Diversity Macroinvertebrate Samples

February	March	April	May	June	July	August	September	October	November
0.0	0.0	50.0	33.3	20.0	21.1	17.0	32.0	11.1	36.4

Mean Percent Relative Diversities of Macroinvertebrates by Month

February	March	April	May	June	July	August	September	October	November
49.0	63.0	37.0	53.5	58.3	64.2	62.7	53.7	52.1	60.3

in the inventory data, definite seasonally-related variations are not particularly distinct with reference to the refined monthly diversity information in Table 22. High diversity samples were most commonly obtained through a June to August period and during the month of November, and lower percentages of higher diversity samples were typically obtained during the other months. At the same time, somewhat high percentages of low diversity samples were obtained in the spring and during the months of September and November. However, even though such percentage differences are evident among the months with respect to the collection of high and low diversity samples, no obvious patterns or definite trends emerge from the diversity data as has been noted for the abundance evaluations, and a similar conclusion can be made in relation to the mean monthly percent relative diversity data of Table 22.

In general, somewhat lower mean relative diversities were obtained for a late winter to late spring period with slightly higher diversities recorded for the summer and fall months. But consistent month-to-month transitions of this kind are not as evident for diversity as they are for total abundance, and numerous discrepancies became evident in the former case. For the most part therefore, and in contrast to the observations for total macroinvertebrate abundance, the diversity levels of the study area streams appear to be generally independent of the seasonal changes within the inventory region, and a large portion of the monthly diversity changes in these waters are best described as largely random in nature.

The significant nonrandomness of the monthly differences and changes in macroinvertebrate abundance and the general randomness and nonsignificance of the monthly differences in diversity can be confirmed statistically through the application of chi-square tests and nonparametric runs analyses (Hoel, 1966) to the data in Table 22. The chi-square tests demonstrated statistically significant differences between the observed number of high and low abundance samples that were obtained during each of the months and the number of high and low abundance samples that would be expected for each of the months as calculated from the overall percentages of high and low total density collections for the entire study. The chi-square (X*) values from these assessments were equal to 27.5 for the high abundance series and 28.3 for the low abundance series, and both of these X* statistics are significant statistically at less than 0.5% with nine degrees of freedom. Subsequent runs analyses of the monthly percentages of high and low abundance collections showed both of these renditions to be nonrandomly distributed among the months with the occurrence of statistically significant trends and patterns within these two sets of numbers. The z test statistics for the high and low abundance runs were equal to -2.68 and -2.01 respectively, and these z values are statistically significant at less than 5% when compared to the standard normal distribution.

In contrast to the abundance evaluations, statistically significant chi-square values could not be obtained from the number of high diversity and low diversity samples that were collected during each of the months after using the same statistical applications. The X*'s were equal to 5.7 and 6.6 in these two cases respectively, and these test statistics are not significant at 10%. Furthermore, the subsequent runs analyses of the high and low diversity data were also found to be insignificant with both of the z's equal to 0.0. These results point to a random arrangement of the high

and low diversity percentages through the ten field months and the occurrence of insignificant random differences in the obtainment of high and low diversity samples through the different seasons of the year. That is, marked seasonal trends and patterns could not be identified in the diversity information. In a similar fashion, a second runs assessment indicated that the monthly mean percent relative diversity data in Table 22 provided for a random arrangement ($Z = 0.0$) without the recognition of any significant trends. However, the mean monthly percent relative abundance data was shown to be nonrandom by this same test ($Z = -2.01$), and the distinct patterns of seasonal increase and decrease in relative abundance that were described earlier can therefore be judged as statistically valid.

As a final statistical application to the data in Table 22, a rank correlation coefficient (Hoel, 1966) was calculated between the ten mean monthly percent relative abundance and diversity pairs. Since the rank coefficient (r_s) proved to be insignificant at 10% with $r_s = 0.26$, this suggests that abundance and diversity acted as independent biological variables in the coalfield region streams.

Inter-Year Differences

Assessment Approach. Since field sampling on the project was conducted through two separate years, attention was also directed towards ascertaining whether differences might have occurred between the two sampling series with respect to the total macroinvertebrate abundance levels of the study area streams and their diversity characteristics. Such an evaluation was of interest because the first field season was somewhat different from the second year meteorologically. The first year's sampling was initiated after a relatively severe winter for the inventory region with a high spring runoff, and it was conducted through a relatively wet, cool, and high flow summer and fall period. In contrast, the second year's sampling followed a much more normal winter with lower spring flows and a reduced scouring effect, and it was conducted through a lower discharge and more normal summer and fall period. One obvious example of the inter-year flow differences can be found in Pumpkin Creek where this stream produced some level of continuous flow into the winter months during the initial inventory year but became intermittent by midsummer during the second field season. Discharge differences were also observed for many of the other creeks in the inventory region with flows during the first sampling period typically greater than those during the second year.

To develop these inter-year analyses, sampling stations were identified where macroinvertebrate samples had been collected during the same month and in each of the separate field seasons, and abundance and diversity ratios between these inter-year, same-month pairs were calculated as follows: P_S/P_F, where P_S denotes either a total abundance or a diversity value that was obtained for a station and month during the second sampling period (1979), and where P_F denotes either a total abundance or a diversity value that was obtained for the same station and month but during the first field series (1978). The diversity and abundance ratios, of course, are calculated separately. If no distinct inter-year differences in abundance or diversity are evident in the study data, then the number of P_S/P_F ratios that are greater than one should be closely equal to the number of P_S/P_F ratios that are less than one in response to a random distribution of the

abundance and diversity differences between the two years. That is, the number of P_S/P_F values that are greater than one should be equal to about 50% in the random case, and vice versa. But if distinct inter-year differences in abundance or diversity are present in the inventory numbers, then the nonrandom case would occur with a significant percentage of the ratios greater than unity or less than unity depending upon which of the two field seasons had the greatest density or diversity levels. A chi-square test can then be used to determine if these percentages are significantly different statistically from the 50% figure that would be expected for a random distribution of inter-year discrepancies.

Data Evaluations. Forty-seven inter-year and same-month comparisons were identified in the study data for application to these assessments. In the case of abundance, 66% of the P_S/P_F ratios were found to be greater than one with 66% of the comparisons thereby showing greater abundance levels for the second year than for the first. A chi-square analysis indicates that this observed percentage was significantly different statistically from the expected 50% random value at less than 5% with X* = 4.78. This result suggests that the second field season with its less severe meteorological conditions produced statistically significant greater total macroinvertebrate abundance levels in the streams than the initial year, at least with respect to the months and stations that were involved in the comparisons.

However, similar results were not obtained for the diversity assessments of this kind. In this case, 55% of the P_S/P_F were greater than one with a X* value of 0.54 that is not statistically significant at the 10% level. Therefore, although the 1979 field season did demonstrate higher diversities than the 1978 period for slightly more than one-half of the comparisons, the nonrandomness of these differences could not be confirmed statistically. Thus in contrast to the observation for abundance, the diversity levels of the macroinvertebrate associations do not appear to have been significantly influenced by the changes in meteorological conditions between the two years.

As a further evaluation, if a mean P_S/P_F ratio is calculated from all of the $P_S > P_F$ monthly data pairs for abundance and diversity and combined with a mean P_F/P_S ratio from all of the $P_S < P_F$ pairs, then these means can be converted through the appropriate manipulations to relative abundance or diversity numbers that describe the overall density and diversity levels of each of the two years in relation to those months and stations that could be included into these inter-year assessments. These added analyses indicate that total macroinvertebrate abundance during the second field season was about 1.8-times greater on the average than the densities that were observed for the first year of sampling. But a similar assessment of the mean diversity P_S/P_F and P_F/P_S ratios provided a much smaller inter-year difference of about 1.15-times which again favored the second year's sampling effort over the initial sampling period, but to a much smaller extent. In general, therefore, various physical factors such as stream flow, intermittency, seasonal changes, and also the occurrence of inter-year meteorological differences seem to have only relatively minor effects on the diversity characteristics of the benthic macroinvertebrate associations, although these same physical factors can have fairly marked effects on the total abundance levels of these same aquatic communities.

RESULTS AND DISCUSSION--ARTIFICIAL SUBSTRATE HABITAT COMPARISONS

GENERAL CONSIDERATIONS AND PHYSICAL FACTORS

The main thrust of the benthic macroinvertebrate sampling program in the southern Fort Union project region was completed by using a Surber sampler as has been noted previously, and most of the interpretations that will have been made from the inventory will be based primarily on this Surber work. This Surber type of sampling involved the collection of macroinvertebrates from the natural substrates that are present on the stream bottom, and it had to be primarily directed to the riffle and channel segments of the streams, ignoring the pools, because of the inherent limitations of the Surber for efficiently collecting stream reaches that lack a fairly pronounced current. As a result, jumbo multiple Hester-Dendy samplers which are not restricted by the absence of a current were also employed during the project as a means of gaining some insights into the characteristics of the macroinvertebrate associations that inhabit the ponded sections of the study area streams. Such non-Surber habitat considerations eventually became the main objective for using the artificial substrates in the sampling program, and the focus of the discussion revolving around the artificial substrate part of the inventory will be largely directed to a comparison of the macroinvertebrate associations that are found in three broadly different stream locations. In addition, some comparisons to the Surber data will be made. However, faunal information of a general nature that is supplemental to the Surber effort was also made available from the jumbo multiplate collections, and all of these artificial substrate data are summarized in the data report (Klarich, et al, 1980) that accompanies this writing. The artificial substrate data are listed in this report by station, by collection date, by inhabitat, by macroinvertebrate taxa, and by the number of organisms that were collected for each of the taxa and habitats along with the taxa's individual biomass levels.

Because of logistic reasons, Hester-Dendy sampling had to be confined to the nine intensive sites that are listed in Table 1. One of the lotic habitats examined by the artificial substrates involved the placement of the jumbo multiplate samplers into the ponded sections of these streams, and for comparative purposes, the samplers were also placed for exposure into the riffle segments in close conjunction to the Surber collections and in close proximity to the ponded reach. These riffle segments were distinct by having relatively rapid current velocities in the vicinity of 1.7 feet per second and shallow depths in the area of 0.5 feet. The pools, in contrast, were about three-times deeper than the riffles (near 1.6 feet on the average) with negligible currents typically less than 0.1 feet per second. In addition, a third habitat or riffle-to-pool location that represents a transition zone or ecotone between the riffle and pool extremes was also examined with the artificial substrates at each of the intensive stations. This riffle-to-pool habitat had intermediate depths relative to the other two locations on the order of one foot, and it also had intermediate current velocities in the vicinity of 0.6 feet per second. As a result of these fairly pronounced physical discrepances among the three different stream locations, some associated differences were anticipated with respect to these habitats' macroinvertebrate communities.

Current velocity and depth measurements were taken at each stream location after the initial placement of the Hester-Dendy's into the water to start an exposure period and after the removal of the samplers from the stream to collect the organisms and terminate a run. Averages of the initial and removal depths, and the initial and removal velocities were then assumed to be representative of the depth and current characteristics of a habitat through a particular exposure period. All of the physical averages that were obtained for each of the individual exposures at a station habitat are presented in the project's data report. Table 23 presents a further reduction and summary of these physical data for each station and habitat as minimum-maximum values and as mean depth and velocity values that were computed across each of the station-habitat's one to four exposure periods. The depth and velocity figures that were used in the previous paragraph to illustrate the physical differences between the three stream locations were taken from the study area averages for depth and current that are included into this same table for each of the habitats.

Some variations in each of the three habitat's physical characteristics at each of the stations became evident during the project as shown by the minimum-maximum differences in Table 23, and intra-habitat physical differences between stations were also observed during the study as shown by each of the habitat's mean variations in depth and current velocity among the nine sampling sites. Such alterations in physical characteristics were unavoidable in the Hester-Dendy applications as a result of the extreme difficulty in consistently finding the exact same conditions in the field between geographically separate locations or between separate exposure periods at the same general geographic spot. Such difficulties were due to flow changes and differences within and between sites and to natural variations in stream morphometry among the several sampling stations. Nevertheless, most of the streams revealed the same general inter-habitat transitions in depth and current velocity as follows: riffle < riffle-to-pool < pool for depth, and riffle > riffle-to-pool > pool for velocity. These physical transitions are quite obvious in the study area means of Table 23, and the three broad habitats that were examined with the artificial substrates, thereby, appear to have been fairly well-defined across all of the intensive waters.

MACROINVERTEBRATE ABUNDANCE

Surber Relationships

Total Numbers. The macroinvertebrate abundance data that were obtained from the artificial substrate work are expressed as the number of individuals of each taxa collected from the duplicate samplers that were placed into each stream habitat and station for any particular exposure period. The total abundance of a station, habitat, and exposure period set was then determined by simply summing the numbers of the individual taxa. Table 24 provides a summary of the total abundance data that were secured through the Hester-Dendy portion of the study, and the artificial substrate data obtained from the riffle habitats should be most equivalent to the densities that were obtained by using the Surber apparatus.

Because of the differences in methodology, the Surber densities and the Hester-Dendy abundance numbers are not directly comparable, and the mean Surber station abundances on a square meter basis were much greater at each

Table 23. Current velocity (feet per second) and depth (feet) characteristics of riffle, riffle-to-pool, and pool stream habitats sampled with artificial substrates in the southern Fort Union region.

Station	Riffle						Riffle-to-Pool						Pool					
	Velocity			Depth			Velocity			Depth			Velocity			Depth		
Symbol	Min*	Max*	Mean	Min*	Max*	Mean	Min*	Max*	Mean	Min*	Max*	Mean	Min*	Max*	Mean	Min*	Max*	Mean
URsb-K	2.5	2.8	2.65	0.5	0.8	0.65	0.7	1.4	0.98	1.0	2.0	1.53	0.1	0.2	0.13	1.4	2.2	1.90
TR-PBB	1.7	2.2	1.95	0.6	0.9	0.75	0.0d	0.9	0.7d	0.4d	1.8d	1.4d	0.3d	0.6	0.5d	1.6d	2.2	1.9d
Sqrrl	2.3	2.3	2.30	0.4	0.5	0.45	0.6	0.8	0.70	1.8	1.8	1.80	0.0	0.0	0.00	1.1	1.2	1.15
UHWC-D	1.1	1.9	1.37	0.3	0.4	0.33	0.2	0.7	0.38	0.4	0.5	0.48	0.0	<.1	<.10	1.2	2.2	1.78
LHWC-B	1.7	2.1	1.85	0.4	0.5	0.42	0.3	0.5	0.43	1.0	1.3	1.15	0.0	0.0	0.00	1.7	2.8	2.28
EFHWC	0.9	1.0	0.95	0.4	0.5	0.45	0.3	0.3	0.30	0.5	0.6	0.55	0.0	0.0	0.00	1.0	1.1	1.05
LOtr-A	0.7d	1.7	1.4d	0.5	1.0d	0.6d	0.4	0.7	0.50	0.8	1.1	0.90	0.0	0.2	0.10	1.0	1.7	1.48
Pmpkn	--	--	--	--	--	--	0.6	0.7	0.65	0.4	0.6	0.50	0.0	0.0	0.00	1.2	1.7	1.45
Mizpah	1.2	1.3	1.25	0.6	0.7	0.65	--	--	0.50	--	--	1.00	<.1	<.1	<.10	1.2	1.3	1.25
Averages	1.51	1.91	1.72	0.46	0.66	0.54	0.39	0.75	0.57	0.79	1.21	1.03	0.04	0.13	0.09	1.27	1.82	1.58

*Minimum and maximum velocity and depth values for each habitat and station. A "d" denotes a marked change in stream stage during the sampler exposure period and an estimated value.

Table 24. Total abundance (number of organisms per duplicate jumbo mulplate samplers) and diversity characteristics of benthic macroinvertebrate associations collected with artificial substrates from riffle, riffle-to-pool, and pool habitats in streams of the coalfield study region in southeastern Montana. Column headings are described in the table footnotes.

Station	Total Abundance											
	Riffle				Riffle-to-Pool				Pool			
Symbol	No	Min	Max	Mean	No	Min	Max	Mean	No	Min	Max	Mean
URsb-K	4	234	1076	593	4	152	879	410	4	76	201	172
TR-PBB	2	544	570	557	3	106	750	498	3	130	600	351
Sqrrl	2	1260	1556	1408	2	972	1289	1131	2	126	259	193
UHWC-D	3	311	544	450	4	24	552	322	4	70	160	134
LHWC-B	4	624	4562	2222	4	60	861	330	4	6	136	51
EFHWC	2	109	720	415	2	113	128	121	2	57	73	65
LOtr-A	3	289	5640	2208	4	73	2888	837	4	29	115	73
Pmpkn	0	--	--	--	2	133	444	289	2	22	96	59
Mizpah	2	5	97	51	1	--	--	36	2	11	15	13
Averages	--	422	1846	988	--	204	974	442	--	59	184	123

Station	Diversity											
	Riffle				Riffle-to-Pool				Pool			
Symbol	T	M_o	SW	e	T	M_o	SW	e	T	M_o	SW	e
URsb-K	13.5	1.96	2.86	0.75	14.0	2.16	3.10	0.86	16.8	3.06	3.09	0.72
TR-PBB	17.5	2.61	3.52	0.95	14.0	2.09	2.82	0.71	14.7	2.34	3.63	1.22
Sqrrl	10.5	1.31	1.95	0.48	14.0	1.85	2.63	0.61	11.0	1.90	1.77	0.40
UHWC-D	10.0	1.47	2.12	0.58	11.5	1.82	2.90	0.91	9.5	1.74	2.91	1.11
LHWC-B	8.0	0.91	1.91	0.74	11.3	1.77	3.08	1.06	5.5	1.15	2.32	1.22
EFHWC	9.5	1.41	2.20	0.65	12.5	2.40	3.14	1.00	8.0	1.68	2.23	0.79
LOtr-A	11.7	1.39	1.78	0.38	11.0	1.49	1.19	0.25	9.3	1.92	2.05	0.59
Pmpkn	--	--	--	--	9.0	1.41	1.85	0.52	7.5	1.59	2.04	0.73
Mizpah	5.5	1.14	1.67	0.74	4.0	0.84	1.22	0.71	3.5	0.97	2.21	1.76
Averages	10.8	1.53	2.25	0.66	11.3	1.76	2.44	0.74	9.5	1.82	2.47	0.95

No--number of station samples collected from each of the habitats. M_o--overall Margalef diversity, SW--Shannon-Weaver diversity, and e--equitability; diversity values calculated from the mean station-habitat data. T--average number of discrete taxa per sample obtained from each habitat and station.

of the intensive sites than those obtained from a riffle habitat using the jumbo multiplate sampler. However on a square foot basis, which was the actual field sampling area of the Surber, the two groups of data are much more equivalent in providing an average deviation between abundance pairs of 38% and a mean difference between groups for all of the applicable stations of only 16% in favor of the Surber collections. Coinciding with this observation, an estimate of the areal aspect of any two jumbo multiplate samplers produced a value that is closely equal to one square foot (about one and one-third square feet), and this feature may account for the general similarity that has been noted in the duplicate artificial substrate and the square-foot natural substrate abundance data. If there is a valid areal comparison between the two collection methods, then the Surber appears to be about one and one-half times more efficient in collecting the macroinvertebrates than the Hester-Dendy samplers.

Similar to the Surber collections, the Hester-Dendy sampling also demonstrated wide variations in total macroinvertebrate numbers among the different stations, habitats, and summer to fall exposure periods (samples) with an extreme 1,130-fold difference evident in Table 24 for the nine intensive sites. If the habitats are held constant, and if the variations between exposure periods are eliminated by using the station averages for each habitat, then the artificial substrates produced much less distinct inter-station differences that were most pronounced for the riffle locations and least pronounced for the ponded reaches as follows: 43-fold for the riffles, 31-fold for the riffle-to-pools, and 27-fold for the pools. These inter-station differences in abundance were somewhat greater for the jumbo multiplate samples than for the natural substrate collections with the latter producing a maximum 18-fold discrepancy for the same nine stations. However, the inter-site abundance patterns that were revealed for the intensive stations were observed to be generally similar for both of the collection methodologies. That is, the EFHWC and Mizpah sites produced relatively low numbers of macroinvertebrates through both of the sampling techniques while the Sqrrl and LHWC-B stations produced relatively high abundances in each of the cases.

The general equivalencies of the two sets of macroinvertebrate abundance data can be additionally illustrated and confirmed statistically where a significant rank correlation coefficient (r_s = 0.76) was obtained between the abundance ranks of the eight station, Surber and Hester-Dendy pairs that involved the riffle habitat of the artificial substrate collections. Furthermore, significant rank coefficients were also obtained between the Surber numbers and the riffle-to-pool and pool habitats with r_s equal to 0.88 and 0.65 in these two instances respectively. All three of the coefficients are statistically significant at less than 5%. These analyses, therefore, tend to support the reality of the density variations that were observed among the streams and stations as a result of the Surber sampling effort, and the inter-stream abundance differences that are shown by the study data, thereby, appear to provide a true picture of the variations of this kind that characterize the lotic benthic biota of the coalfield region.

Numbers by Taxa. Table 25 presents the taxa abundance values that were obtained via the Hester-Dendy macroinvertebrate collections from the riffle habitats at each of the eight intensive stream stations, and this table also contains the study area means for each of the taxa with reference to the

Table 25. Study area mean abundance (SAM) and average station abundance (number of individuals per duplicate Hester-Dendy samplers) of major benthic macroinvertebrate taxa collected with artificial substrates from stream riffle habitats at the intensive sampling sites in the coalfield study area.

Taxa	URsb-K	TR-PBB	Sqrrl	UHWC-D	LHWC-B	EFHWC	LOtr-A	Mizpah	SAM
Curculionidae	--	--	--	--	1.0	--	--	--	0.1
Helichus	--	--	--	0.7	--	1.5	--	0.5	0.3
Dubiraphia	0.3	17.5	2.0	0.3	1.0	--	--	--	2.6
Microcylloepus	2.1	119.0	4.0	--	2.0	--	14.6	--	17.7
Optioservus	2.5	--	6.0	--	--	--	--	--	1.1
Stenelmis	--	17.5	--	--	--	--	5.3	--	2.9
Hemerodromia	4.5t	--	14.0t	0.3t	24.0t	--	9.3t	--	6.5t
Muscidae	--	--	4.0	--	--	--	--	--	0.5
Bezzia-Probezzia	--	--	2.0	--	--	2.0	--	--	0.5
Chironomidae	70.8	19.0	314.0	21.3	323.5	27.0	1254.	12.0	255.2
Simulium	10.8	4.5	102.0	174.7	1131.	146.5	573.7	--	267.9
Dicranota	3.0	--	14.0	--	--	4.0	--	--	2.6
Baetis	44.3	35.5	--	--	1.0	165.5	--	0.5	30.9
Caenis	--	--	--	--	2.3	--	7.3	32.0	5.2
Heptagenia	5.5	--	--	--	--	--	--	--	0.7
Stenonema	1.0	8.0	--	--	--	--	--	--	1.1
Choroterpes	0.5	64.0	--	--	--	--	--	--	8.1
Leptophlebia	6.0	--	--	--	--	--	--	--	0.8
Paraleptophlebia	4.0	--	--	--	--	1.5	--	--	0.7
Ephemerella	--	29.0	--	--	--	--	--	--	3.6
Tricorythodes	24.3	37.5	--	--	--	--	--	--	7.7
Ambrysus mormon	--	3.0	--	0.7	--	--	2.7	1.0	0.9
Hetaerina	--	--	--	12.7	1.8	--	10.7	--	3.2
Argia	--	--	--	--	--	--	4.0	--	0.5
Ischnura	--	--	--	0.3	--	--	2.7	1.0	0.5
Chloroperlidae	--	13.0t	--	--	--	--	--	--	1.6t
Isoperla	12.0	--	--	--	--	--	--	--	1.5
Brachycentrus	14.5	--	4.0	--	--	--	--	--	2.3
Helicopsyche	--	4.0	--	--	--	--	--	--	0.5
Cheumatopsyche	79.0	3.0	158.0	137.3	495.8	4.0	215.3	1.0	136.7
Hydropsyche	242.3	4.5	766.0	7.0	209.3	4.0	13.0	--	155.8
Hydroptila	61.5	3.0	14.0	1.0	24.3	10.0	82.3	--	24.5
Ithytrichia	--	0.5	--	0.7	--	--	--	--	0.2
Nectopsyche	--	40.0	--	--	--	--	--	--	5.0
Oecetis	--	4.0	--	--	--	--	--	--	0.5
Hesperophylax	--	--	--	--	--	41.5	--	--	5.2
Limnephilus	--	--	--	1.0	--	1.0	--	--	0.3
Polycentropus	--	--	--	--	--	--	1.3	--	0.2
Hyalella azteca	--	--	--	0.3	--	2.0	--	1.0	0.4
Acari	--	--	2.0	0.3	--	--	--	--	0.3
Ferrissia	1.5	--	--	--	--	--	--	--	0.2
Gyraulus	0.5	--	2.0	2.0	--	--	--	--	0.6
Physa	1.8	12.5	--	89.7	5.0	2.0	4.0	2.0	14.6
Pisidium	--	--	--	--	--	--	2.7	--	0.3
Turbellaria	--	115.0	--	--	--	--	--	--	14.4
Nematomorpha	--	--	--	--	--	--	5.3	--	0.7

artificial substrate work. The Pumpkin Creek site could not be included into this tabulation because, as noted in Table 24, none of the riffle samplers were recovered from the stream after the exposure period. The reasons for this non-recovery are given in the data report. The riffle data are presented for the taxa in Table 25 because the numbers from this habitat should be most closely comparable to the density values that were obtained from the natural substrate collections. However, the major taxa listing in Table 25 should also be applicable to the riffle-to-pool and pool habitats, as are the abundance relationships to some degree, and the inter-habitat differences that were observed in taxa dominance will be illustrated later in this report by using a different assessment approach.

Only the more abundant macroinvertebrate groups are listed in Table 25, and the taxa that are included account for two-thirds of the discrete taxa that were collected with the jumbo multiplate samplers. These same major taxa also provide nearly 100% of the total Hester-Dendy macroinvertebrate abundance that was obtained from the riffle habitats of the intensive streams. The remaining one-third of the taxa can be viewed as the minor or rare forms in the artificial substrate collections and in the study region, and although these contribute to stream diversity to some extent, they are unimportant from an abundance standpoint. Such minor taxa are listed in Table 26, and many of these minor listings represent a set of higher taxa for which a few speciments could not be keyed to the generic level. Also, many of them just appear to be generally rare in the study region as was shown by the Surber sampling program and some of them, such as the Corixidae, Saldidae, Aeshna, Ormosia, and Ptilostomis, have to be classified as generally non-benthic organisms. In this latter case, the rarity of these animals in a benthic-type of collection, as with the Hester-Dendy's was not unexpected for this study.

As illustrated in Table 25, and similar to the Surber density data, the number of individuals of a taxa that were collected with the Hester-Dendy's, like the case for abundance, demonstrated fairly marked variations among the intensive stations in response to the differing environmental conditions of the streams. In addition, marked abundance differences also became evident among the taxa at each of the stations with the occurrence of a few very abundance organisms and with a large number of taxa showing low or moderate abundance levels. This type of pattern is identical to the one that has been described for the natural substrate collections. After calculating the mean study area, PRA values of the taxa, a community structural organization was recognized that is most closely equivalent to the low-dominance option that is summarized in Table 21 with the following PRA values for the top-ranked taxa: (1) 27.1%, (2) 25.8%, (3) 15.8%, (4) 13.8%, (5) 3.1%, (6) 2.5%, and so on to (12) 0.7% and to (42) 0.02%. Thus, the macroinvertebrate associations that were "grown" in relation to the riffle jumbo multiplate samplers had a structure that would be generally predicted by the broken stick model.

Although some differences in faunal composition became evident between the natural substrate and artificial substrate collections, the mean study area PRA's of the taxa and their abundance rankings were largely similar between the two sets of data for many of the taxa wherein 70% of the thirteen top-ranked taxa were common to both of the cases in the same general pattern. As a result, a rank correlation coefficient between the abundance

Table 26. Listing of minor macroinvertebrate taxa that were collected from the study area streams by using the jumbo multiplate samplers.

DIP: Empididae*
- Clinocera
- Palpumyia
- Psychodidae*
- Tipulidae*
- Tipula

EPH: Ephemeroptera*
- Ephemera
- Heptageniidae*
- Leptophlebiidae*

HEM: Corixidae*
- Hesperocorixa vulgaris
- Saldidae

MEG: Sialis

ANI: Aeshna
- Gomphus
- Ophiogomphus

ZYG: Zygoptera*

PLE: Acroneuria

TRI: Anabolia
- Ptilsustomis
- Neureclipsis
- Nyctiophylax

OST: Ostracoda

HIR: Hirudinea*
- Placobdella papillifera

OLI: Oligochaeta

GAS: Helisoma
- Columnella

PEL: Pelecypoda*
- Sphaerium

*Denotes the collection of a few higher taxa representatives that could not be taken to the generic level.

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rankings of the top-ranked taxa in the two sets was found to be statistically significant at less than 1% with $r_s = 0.64$. Major differences between the Hester-Dendy and Surber nimbers were identified as the lower relative abundances of Brachycentrus, Hyalella azteca, the oligochaetes, Acari, the leeches, and some of the Elmidae in the jumbo multiplate samples than in the Surber samples, and as the lower relative abundances of the flatworms, Chloroperlidae, Nectopsyche, Isoperla, Choroterpes, and Tricorythodes in the Surber than in the Hester-Dendy retrievals.

The faunal variations, noted above between the artificial and natural substrates could be due in part to a "screening" action of the Hester-Dendy samplers which would eliminate certain of the organisms but favor some of the other types of macroinvertebrates. For example, the burrowing animals might not opt to utilize the Hester-Dendy's because of their foraging requirements, while the larger organisms would not be able to take advantage of the samplers' "hidey-holes" because of the animals' excess size. In contrast, the clinging, sprawling, and retreat kinds of macroinvertebrates would tend to migrate to the samplers for habitation because the samplers more closely simulate their natural habitat requirements. However, a portion of the faunal discrepancies that were observed between the natural and artificial substrates was also probably due to the fact that the artificial substrate means were based on a smaller assortment of data (eight stations) than the Surber summaries (thirty-five stations) which would also bias the comparisons to some extent. In any event, the Chironomidae, Microcylloepus, Simulium, Baetis, Caenis, Cheumatopsyche, Hydropsyche, Hydroptila and Physa provided similar abundance rankings for both of the substrates so that the two sampling techniques did not produce totally different kinds of faunistic data.

As a further observation, a faunal classification of the streams that is based on the artificial substrate data would be generally similar to the scheme that is presented in Table 16 for the Surber work with the URsb-K and Sqrrl sites listed as Hydropsychidae/Chironomidae creeks, with the TR-PBB station listed as an Elmidae stream,with the three Hanging Woman Creek stations listed as Simuliidae/Hydropsychidae streams, and with the LOtr-A site listed as a Chironomidae/Simuliidae water. Mizpah Creek provides a major exception which may be a reflection of the low jumbo multiplate collection success that was encountered with this particular system. For the most part, therefore, these artificial substrate data act to confirm the validity of the faunal composition and abundance descriptions that were developed for the streams from the more extensive Surber phase of the inventory.

Habitat Differences

Of primary interest to this artificial substrate discussion are the inter-habitat differences in total abundance that became evident in the various streams. These relationships are illustrated in Table 24, and although some variations were observed among the stations with respect to the amount of abundance change between the habitats, all of the intensive stations consistently provided much higher total counts for the riffle location over the ponded reaches with the riffle-to-pool habitat occupying a somewhat intermediate position. These transitions are obvious in the study area means, and a two-way ANOVA of the data in Table 24, with blocking on the stations to eliminate the inter-site variations, produced an F-ratio (F^{2}_{14} = 6.56) that was significant at less than 1%. Thus, the inter-habitat differences in total abundance are statistically significant with the riffles showing much higher, 1.6-fold to 43.6-fold levels of secondary production than the pools, depending upon the stream. On an average basis, the total macroinvertebrate abundance levels of the study area waters were 2.2-times and 9.0-times higher in the riffles than in the riffle-to-pool and pool habitats respectively, and they were 7.9-times higher in the riffle-to-pool locations than in the ponded segments.

A somewhat surprising result also emerged from these same ANOVA analyses in the general insignificance of the block F-ratio (F^{7}_{14} = 1.78) that tested the total abundance differences between the eight intensive stations. This F value was significant at only about 18%, and although mean differences are evident among the stations in this regard, they could not be confirmed statistically at a high level of probability because of the wide fluctuations in individual sample abundances that were obtained from each of the streams. For this same reason, a one-way, completely random ANOVA of the numbers from each of the exposure periods at the eight sites was also insignificant statistically for the riffle habitat with F^{7}_{14} = 1.12.

The variations that were noted for the streams in terms of the magnitude of their abundance declines between the riffle habitats and the pool habitats seemed to be related to some extent to the physical characteristics of the ponded stream segment that was chosen to represent the pool location. That is, smaller inter-habitat abundance differences were obtained for those stream stations such as URsb-K and TR-PBB where the pool habitat was somewhat riffle-like in character in having some current velocities at the point of placement of the duplicate jumbo multiplate samplers. In contrast, higher

inter-habitat differences in abundance were generally obtained from sites like LHWC-B where the ponded segment was more definitely pool-like with a relatively distinct depth and with the absence of a measurable current through all of the exposure periods. As a result, the LHWC-B station is probably most descriptive of the macroinvertebrate abundance changes that actually occur in moving from a riffle habitat to a stream bottom location that is found in the ponded reach of a southern Fort Union stream.

The differences in abundance that were observed between the broadly defined stream habitats have some implications from a management standpoint where efforts should be expended to maintain the integrity of the riffle reaches of the streams in order to ensure a continuance of the waters' fairly high levels of secondary production which are of benefit to the streams' fishery and to the other higher trophic categories. Such concerns appear to be particularly applicable to the coalfield region since the natural morphometry of many of the creeks dictates a low riffle: pool areal ratio with the occurrence of fairly short riffle sections interspersed between relatively extensive segments of ponded waters. However, riffle production becomes increasingly less important to a drainage as the extent of the riffles decline and as the riffle:pool ratios approach some excessively low number. But at the same time, the contribution of each riffle section to the biological completeness of the entire stream becomes increasingly more important as the extent of the riffles decrease along a long stretch of water.

To illustrate these abundance features, the data from the LHWC-B site (Table 24) can be used as a typical example of the inter-habitat secondary production relationships that were found within these streams. If a 1:100, riffle:pool areal ratio is assumed for the creek with a riffle:pool abundance ratio of 43.6, then a 30% decline in macroinvertebrate density could occur through a segment of the creek following the elimination of its riffle reaches. This reduction is more distinct with a 1:10 areal ratio (80%) and less distinct with a 1:1000 ratio (4%), but it is still fairly significant even in the latter instance. However, such percentage reductions in density become smaller and less significant as the differences in abundance between the riffles and pools become less pronounced. In the case of the LOtr-A site for example with its lower 30.2, riffle: pool abundance ratio, the density declines would equal 22% after the elimination of its riffle segments under the 1:100 areal assumption. But for the most part, all of these considerations eventually become unimportant from the viewpoint of secondary production regardless of the riffle: pool abundance relationships when the riffle:pool areal ratios approach 1:100,000 since the density losses would then be well below a 1% value in such cases, although they could have some local significance in relation to those specific waters that are more closely associated with each particular riffle. And from another perspective, the riffle sections become very important in a 1:100,000, riffle:pool scenario in terms of each riffle's contribution to the biotic wholeness of the entire stream as was suggested previously.

Computations that were based on some extremely crude measurements of riffle and pool dimensions in the vicinity of the LHWC-B site indicate that the riffle and pool macroinvertebrate density differences within this creek could be fairly important to its secondary production levels with a riffle:pool areal ratio probably someplace in between the 1:10 and 1:1000

figures. A riffle:pool areal estimate of 0.06 was obtained from these calculations, and if this figure happens to be anyplace in the ballpark for one that accurately describes the stream, then a 60% decline in stream secondary production might be anticipated with reference to the Table 24 abundance data if the riffle sections of the lower Hanging Woman Creek drainage should happen to be obliterated to a significant extent. Of course, much more exact field data describing the dimensions of the riffle and pool reaches will have to be gathered before the effects of riffle alteration on the macroinvertebrate abundance levels of Hanging Woman Creek and the other streams of the study region can be accurately judged to any degree of reliability. Nevertheless, the data obtained in this inventory do point to the general biotic importance of the riffle sections to these lotic systems.

MACROINVERTEBRATE DIVERSITY

Surber Relationships

Because of the differences in macroinvertebrate collection techniques, the magnitude of the overall Margalef diversity index from the artificial substrate work in a riffle habitat is not directly comparable in a theoretical sense to the Margalef value that was obtained from the Surber samples for the same site. Nevertheless, the Margalef index did produce closely similar patterns of diversity among the intensive stations for both of the sampling applications, and a significant rank correlation coefficient of $r_s = 0.77$ was obtained from a comparison between the artificial substrate and natural substrate Margalef diversities at each of the stations. Furthermore, the diversity values were quite similar for the stations between data sets where the Margalef afforded an average discrepancy of 17% between the two types of collections, and no trends became obvious in the data to suggest that any one of the two sampling approaches produced higher diversity levels. These similarities point to the fact that the areal components of the Hester-Dendy samples and that of the Surber apparatus were adequately similar to produce the same general interpretative results with reference to the Margalef diversity evaluations. Thus, the Margalef appears to be a suitable estimator of the SW index with respect to the artificial substrate work.

In contrast to the Margalef index, the Shannon-Weaver diversity values that were calculated from the Surber samples and from the riffle Hester-Dendy samples of a station were expected to be directly comparable to each other since the SW expression should be largely independent of any variations in sampling methodology which is one of this index's main advantages. As a reflection of this independence, the SW produced a smaller station deviation in diversity than the Margalef between the two sets of data that averaged only 9.2% across all of the stations. In addition, the SW provided for a slightly higher rank correlation coefficient of $r_s = 0.82$ between its diversity pairs than the other index. Thus the artificial substrate collections made largely similar predictions from both the Margalef and from the SW viewpoints as the natural substrate work concerning the environmental stress characteristics of the intensive streams and the general health of their benthic biota, and the results from the Hester-Dendy samples tend to confirm those that were obtained from the more

extensive Surber applications in the coalfield study area.

Habitat Differences

The average artificial substrate diversity values in Table 24 for the nine intensive stations indicate that a general and relatively small inter-habitat increase in diversity occurred in the streams in going from the riffle locations with their swifter current velocities and shallower depths to the ponded segments with their slow to negligible current and their greater depths, and the physically intermediate riffle-to-pool habitats also occupied an intermediate position with respect to their diversity levels. This same tendency is evident in both the Margalef and the SW values, and the pools demonstrated 1.1-times to 1.2-times higher average diversities than the riffles depending upon the index. The equitability index provided a much more pronounced increase in magnitude than diversity in the same direction with a 1.4-fold difference in e between the riffles and pools. These results suggest that the pool habitat, while having a lower density of individuals, had macroinvertebrate associations that were slightly more diverse and more equitable in their structure with a lower degree of single taxa dominance than was the case for the higher abundance communities that inhabited the riffle locations. However, the study area averages only point to the occurrance of overall trends of this kind in the streams, and numerous exceptions to these trends became evident in all three of the indices when looking at the data for each of the individual stations. Thus in contrast to the inter-habitat case for abundance that was described previously, the inter-habitat differences in diversity are not all that consistent and well-defind when viewing any particular station.

The cloudiness of the inter-habitat differences in diversity is further described by a statistical assessment of the SW data in Table 24 where a two-way ANOVA with blocking on the stations produces a low treatment F-ratio (F^{2}_{14} = 0.88) that is not significant at 10% and not significant at less than 25%. The mean inter-habitat differences in diversity, therefore, could not be confirmed statistically at a high level of probability, and from a statistical standpoint, these differences would have to be graded as insignificant because of the inconsistent and wide inter-habitat variations in diversity that can be obtained at any of the nine stations. As a result, this assessment affords another example of the fact that although physical factors in the streams can have marked effects on the macroinvertebrate abundance levels of the waters, these same physical factors have only a minor influence on the diversity characteristics of the macroinvertebrate associations, and this is also true for the physical changes that occur along a riffle to pool transition.

In contrast to the habitat comparisons, the inter-station diversity differences that are evident in Table 24 for each of the habitats were shown to be statistically significant through the same ANOVA application with a block F-ratio that was significant at less than 1% (F^{7}_{14} = 4.77). Since the streams' physical features have been largely eliminated as potential affecting factors with respect to a lotic water's diversity levels, some other kinds of factors or combination of nonphysical factors must be causing the obvious and statistically significant inter-station diversity differences that were observed during the inventory. Since salinity levels also show a marked variation among the streams, this water quality parameter

provided a prime candidate for further diversity assessments, and the results of the salinity analyses will be described in a later section of this report.

TAXA ENCOUNTERED

Surber Relationships

As noted previously, the kinds of dominant macroinvertebrate taxa that were collected during the project were found to be largely similar in both the artificial substrate and natural substrate samples, and these dominant taxa were observed to have the same general patterns of abundance through both of the collections which acts to validate the results of the study. This taxa similarity between the sets of natural substrate and artificial substrate data can be additionally confirmed through the use of a percentage similarity evaluation that compares the mean taxa abundance data of each station that were obtained through the Surber work with the abundance data that were obtained via the riffle Hester-Dendy retrievals. A mean percentage similarity value of 68% was obtained from this assessment for the eight intensive stations, and this relatively high percentage points to the occurrence of a significant taxa similarity component between the two sampling methodologies.

Even though most of dominant macroinvertebrate taxa in the study area streams were retrieved from the waters through both the artificial substrate and natural substrate sampling techniques, a fairly large assortment of the less abundant organisms that were uncovered with the Surber sampler were not collected with the Hester-Dendy apparatus, and these particular taxa are summarized in Table 27. In addition, a small group of generally low abundance and non-ubiquitous taxa were picked up only by the jumbo multiplate samplers to their exclusion from the Surber collections, and these few unique organisms have been listed earlier in this report. However, these non-Surber taxa proved to be generally insignificant in relation to the lotic benthic ecology of the study region, although their uncovery did increase the project's species list to some extent.

The macroinvertebrate taxa that were obtained in both kinds of collections were most typically the truly benthic forms that were relatively abundant and important in the stream benthos, while many of the animals that were retrieved only by the Surber were generally unimportant and collected in relatively small numbers. Furthermore, many of the Surber-only organisms could not be classified as benthic forms in having the climbing, swimming, diving, or limnetic habits that were described previously for the non-benthic animals (Table 7). These non-benthic organisms were occasionally collected by the Surber as temporary benthic visitors or by accident, but their occasional retrieval for these same reasons by the Hester-Dendy samplers would be much less likely since the artificial substrate collection methodology is much more closely linked by its design to the stream bottom than is the case for the Surber technique. This particular feature of the Hester-Dendy acts to eliminate any intrusion on the adjacent habitats, and the artificial samplers, thereby, show a much lower probability for accidentally collecting a non-benthic form than what has been observed for the natural substrate collections. Also, some of the organisms that were not collected by the artificial substrates were observed to be rela-

Table 27. Macroinvertebrate taxa identified in the study region streams through the Surber collections but not recognized in any of the artificial substrate samples.

COL: Carabidae
Donacia
Hyperodes (a)
Listronotus (a)
Agabus
Deronectes sp.
Deronectes liodessus
Deronectes-*Oreodytes* complex
Oreodytes
Hydroporus-*Hygrotus* complex
Rhantus
Dubiraphia vittata (b)
Optioservus divergens (b)
Optioservuus quadrimaculatus (b)
Stenelmis sinuata (b)
Stenelmis vittipennis (b)
Zaitzevia parvula
Haliplus
Heteroceridae
Berosus
Enochrus
Helophorus
Hydrochus
Laccobius
Ochthebius
Gyrinis-*Gyretes* complex
Limnichidae

DIP: Dolichopodidae
Euparyphus
Nemotelus
Odontomyia
Stratiomys
Chrysops
Tabanus
Hydrellia
Limnophora (a)
Scatophagidae
Culicoides

DIP: *Dixa*
Pericoma (a)
Ormosia
Pseudolimnophilia

EPH: *Pseudocloeon*
Rithrogena
Ephoron
Ameletus
Siphlonurus

HEM: *Hesperocurixa laevigata*
Sigara comani
Sigara trillineata
Trichocorixa
Gerris remigis
Homoptera

LEP: *Parargyractis*

MEG: *Dysmicohermes*

ANI: *Leucorrhinia*

PLE: *Nemoura*
Isogenus

TRI: *Culoptila*
Potamyia
Ochrotrichia
Glyphopsyche
Onocosmoecus
Psychoglypha

AMP: *Gammarus*

HIR: *Percymourensis marmoratis* (c)
Dina anoculata (c)
Erpobdella (c)
Batracobdella (c)
Glossiphonia sp. (c)
Glossiphonia complanata (c)
Helobdella sp. (c)
Helobdella stagnalis (c)

GAS: *Lymnaea*

PEL: Unionidae

NEM: Nematoda

(a) Specimens of these macroinvertebrate families were identified from the Hester-Dendy samplers, but they could not be taken to genera.

(b) Members of these genera were identified in the Hester-Dendy samples, but the specimens could not be taken to species.

(c) Specimens of this macroinvertebrate class were identified from the Hester-Dendy samplers, but they could not be taken to lower systematic levels.

tively rare in the study region, and they were probably not retrieved by the Hester-Dendy applications simply because this phase of the inventory was much less intensive and involved a smaller assortment of stations than the Surber work.

As another option for non-collection by the Hester-Dendy's, these samplers could act to "screen-out" certain of the organisms such as the leeches as was indicated earlier, and these "screened" animals would then not be recorded for an artificial substrate collection. In the main, therefore, the taxa encountered with the jumbo multiplate samplers represent the main care of faunal composition and taxa abundance in the benthos of the project area streams as summarized in Tables 25 and 26, although some bias was introduced into the artificial substrate data because of the design and inherent limitations of this particular sampler. This same general core of study data was also produced with less bias for the riffle reaches by the Surber collecting efforts in the field, and the Surber, because of its less restrictive design and applications, and because of its more intensive and extensive use in the field, also provided for extra data that described the fringes of taxa composition and abundance in the study region. However, the same general conclusions can be derived from the information that was developed by both of the sampling methodologies, although the inter-habitat benthic comparisons had to be solely dependent upon the applications of the Hester-Dendy apparatus.

Habitat Differences

Community Evaluations. A survey of the taxa artificial substrate abundance data that are available in the project data report for the stream habitats at each of the intensive sites points to the occurrence of fairly distinct faunal compositional changes between the three benthic locations. The reality of these inter-habitat faunal variations was eventually confirmed through the application of percentage similarity (PS) evaluations that were used to make comparisons among the riffle, riffle-to-pool, and pool habitats at each of the stations. These assessments produced the following mean PS values for the nine intensive sites as presented in the order of their magnitude: riffle-to-pool X pool at 60.4%, riffle X riffle-to-pool at 50.2%, and riffle X pool at 36.4%. The riffle-to-pool and pool comparisons showed the greatest similarity in faunal composition with the riffle-to-pool habitat being more similar faunistically to the ponded reach than to a riffle location. This particular gradation of PS values was largely expected for the analysis with the greatest faunal dissimilarity observed for the riffle and pool comparison in response to the fact that these two stream locations were the most distinctly separated in terms of their physical characteristics. Furthermore, the riffle-to-pool habitat was somewhat more similar physically to the pool locations than to the riffle reach of a stream, and this aspect is also reflected by the PS relationships.

In any event, and in contrast to the case for diversity, the results from these PS evaluations confirm the actuality of marked faunal alterations along a riffle-to-pool physical transition in accompaniment with the changes that were observed for total abundance. Further evaluations along these lines were directed towards establishing the individual habitat preferences of the dominant macroinvertebrate taxa in the streams by using a

taxa importance value approach that was developed for this particular study.

Taxa Assessment Approach. Since pronounced inter-habitat total abundance differences did occur within each of the study region streams, a semi-quantitative evaluation had to be developed as a means of judging the inter-habitat proclivities and changes that were expressed by the various macroinvertebrate taxa. This assessment involved the calculation of overall riffle, riffle-to-pool, and pool habitat importance values for each of the taxa, and these importance values were calculated through a stepwise procedure that can be summarized as follows: First, the twelve most abundant organisms at each habitat-station were ranged according to the numbers that were collected with the most abundant taxa having a rank of one and with the twelfth most abundant taxa having a rank of twelve. These ranked macroinvertebrates typically accounted for about 95% of the total Hester-Dendy abundance at the stations. As a result, the unranked taxa were considered to be unimportant at any stream location, and they were thereby excluded from any direct participation in the remaining calculations.

As the second step of these analyses, a station importance value for a habitat was determined for each ranked taxa as thirteen minus the organism's rank so that the number one taxa had a grading of twelve for that particular situation, and this continued to the twelfth ranked taxa which had a station importance value of one. The unranked taxa were automatically assigned on importance value of zero. The importance values of each taxa were then summed individually by habitat across all of the stations, and as a final step, these summed numbers were divided by either one of two figures to describe their overall habitat importance on the basis of the entire study area or on the basis of those sampling sites where the organisms exhibited some degree of faunal dominance and abundance in any of the sampling locations. For the study area habitat importance expressions, the summed values were divided by twelve times the total number of sites involved in the assessment, equalling either eight or nine stations depending upon the habitat. For the sampling site habitat importance expressions, the summed values were divided by twelve times the number of sampling sites at which the taxa was found to be among the twelve most abundant macroinvertebrates in the habitat under consideration. Both of these fractional importance values were ultimately converted to a percentage scale as the format for their final presentation.

With reference to these importance assessments, if a taxon should happen to be ranked number one in any one of the three habitats through all of the stations, then it would have a study area importance value of 100% for that habitat. In contrast, if a taxon should happen to be unranked in a particular stream location through all of the stations, then it would have a study area habitat importance value of 0%. In turn, if a taxon should happen to be ranked sixth in a habitat across all of the stations, then it would have a study area importance value of 50% for that stream location. A wide variety of importance percentages are, of course, possible between these extremes depending upon the different taxa's habitat abundance rankings at each of the stations, and as the relative abundances of the organisms happen to change with respect to each other in going from one stream location to another, this feature should be reflected by alterations in the comparative magnitudes of the macroinvertebrates' importance gradings for the three habitats. In addition, these importance values also describe

the relative project region dominances of the various taxa in the artificial substrate collections from the nine intensive streams.

If a taxon is ranked or unranked in a habitat through all of the sampling sites, then its study area importance value is identical to one that is calculated on a sampling site basis. But if a taxon is ranked at some station but unranked at others, then its sampling site percentage is greater than the study area percentage with the station value describing the importance of the organism only in relation to those sites where it was found to be fairly dominant. In some instances, these two numbers can show a fair degree of difference if an animal happens to be uniquely abundant in a habitat but only at one or two of the stations while being unranked at the remaining sites. Thus, the calculation of these sampling site importance values provides another interpretive option for the data evaluations in terms of defining the local dominance of an organism and both of these numbers can be used in concert to judge the general habitat preferences of the many benthic organisms.

Taxa Evaluations. Table 28 presents the study area and the sampling site importance numbers that were calculated for the applicable taxa in each of the three habitats. As indicated in this table, both the study area and the sampling site values demonstrated a great deal of variability among the taxa in each of the habitats, ranging from zero in 29% of the cases to a few high values that were in excess of 80%, and one importance reading of 100% was obtained from the analysis. Therefore, some of the macroinvertebrates were shown to be quite dominant in a habitat as illustrated by the high importance rankings of these organisms in Table 28, while many of the remaining taxa with their lower rankings were judged to have a much less influential role in the biotic communities. This observation generally coincides with the one that was made in relation to the actual abundance data, although the riffle-to-pool and pool options could also be considered in these importance evaluations. In the main, generally similar patterns of importance values were found in all three of the habitats, but most of the importance ranking in the three cases were occupied by different taxa depending upon the particular stream location.

Of more interest to the main objective of this assessment were the consistant changes in importance values that were obtained for many of the taxa across the three habitats, and this feature points to the occurrence of faunal compositional changes in the streams' macroinvertebrate associations in going from the riffle to the pool locations, and vice versa. Although many of the taxa were collected from all three of the habitats, their importance ratings were often significantly greater in one of the cases than in the others, and in many instances, an organism was found to be totally unimportant in one or two of the habitats in having an importance value that equalled zero. About one-half of the taxa would fall into this latter category. Such inter-habitat faunal changes can be most readily recognized through a comparison of the taxa's importance rankings in the three stream locations (Table 28), and these comparisons indicate that almost one-half of the top twenty ranked macroinvertebrates in the riffle habitat were not ranked as one of the twenty most dominant organisms in relation to the pool environment. Other examples of inter-habitat faunal changes of this kind can also be recog-

Table 28. Importance values of major macroinvertebrate taxa collected with artificial substrates from the riffle, riffle-to-pool (R-to-P), and pool stream habitats at the intensive sampling stations in the coalfield study area (the first page of two pages). Column headings are described in the table footnotes on the following page.

Taxa	General* Habitat Preference	Importance Values and Taxa Ranks: Riffle I. R.	Riffle S. A.	Riffle S. S.	R-to-P I. R.	R-to-P S. A.	R-to-P S. S.	Pool I. R.	Pool S. A.	Pool S. S.
Chironomidae	Pool-U	1.	80.2	80.2	1.	86.1	86.1	1.	94.4	94.4
Cheumatopsyche	Riffle-U	2.	71.9	82.1	2.	58.2	79.2	4.	45.4	58.3
Simulium	Riffle-U	3.	61.5	81.9	5.	38.9	70.0	11.	23.1	52.1
Hydropsyche	Riffle-U	4.	56.3	75.0	3.	49.1	63.1	8.	27.8	50.0
Hydroptila	Riffle	5.	49.0	65.3	6.	37.0	55.6	33.	0.0	0.0
Baetis	Riffle-U	6.	35.4	56.7	11.	14.8	44.4	22.	8.3	33.3
Physa	Pool-U	7.	33.3	44.4	4.	49.1	63.1	3.	51.9	58.3
Microcylloepus	Riffle-U	8.	30.2	60.4	10.	18.5	33.3	21.	9.3	83.3
Hyalella azteca	Neutral-U	9.	24.0	63.9	9.	23.1	52.1	10.	26.9	60.4
Caenis	Pool-U	10.	21.9	58.3	7.	28.7	64.6	2.	56.5	84.7
Hetaerina	Riffle	11.	17.7	47.2	13.	13.9	41.7	34.	0.0	0.0
Tricorythodes	Neutral-U	12.	15.6	62.5	22.	9.3	41.7	16.	10.2	45.8
Dicranota	Riffle	13.	15.6	62.5	37.	0.9	8.3	35.	0.0	0.0
Hemerodromia	Riffle	14.	13.5	36.1	16.	11.1	33.3	36.	0.0	0.0
Ambrysus mormon	Riffle	15.	12.5	50.0	40.	0.0	0.0	37.	0.0	0.0
Brachycentrus	Neutral-U	16.	11.5	45.8	12.	14.8	66.7	17.	10.2	91.7
Turbellaria	Neutral-U	17.	11.5	91.7	25.	8.3	75.0	23.	8.3	75.0
Hesperophylax	Riffle	18.	10.4	25.0	20.	10.2	91.7	38.	0.0	0.0
Choroterpes	Neutral-U	19.	10.4	83.3	17.	11.1	50.0	18.	10.2	45.8
Nectopsyche	Neutral-U	20.	9.4	75.0	18.	11.1	100.0	19.	10.2	91.7
Ischnura	Neutral	21.	9.4	75.0	41.	0.0	0.0	7.	28.7	51.7
Gyraulus	Riffle	22.	8.3	33.3	32.	3.7	33.3	39.	0.0	0.0
Dubiraphia	Pool-U	23.	8.3	22.2	8.	28.7	50.0	6.	36.1	54.2
Helichus	Riffle	24.	8.3	33.3	42.	0.0	0.0	40.	0.0	0.0
Stenelmis	Pool-U	25.	7.3	29.2	21.	10.2	91.7	13.	14.8	44.4
Bezzia-Probezzia	Neutral-U	26.	6.3	25.0	29.	4.6	41.7	26.	6.5	58.3
Ephemerella	Riffle	27.	6.3	50.0	43.	0.0	0.0	41.	0.0	0.0

Table 28. Continued (the second page of two pages).

Taxa	General* Habitat Preference	Importance Values and Taxa Rank								
		Riffle			R-to-P			Pool		
		I. R.	S. A.	S. S.	I. R.	S. A.	S. S.	I. R.	S. A.	S. S.
Optioservus	Riffle	28.	6.3	50.7	34.	2.8	25.0	42.	0.0	0.0
Limnephilus	Neutral-U	29.	5.2	41.7	26.	7.4	33.3	31.	3.7	33.3
Muscidae	Riffle	30.	5.2	35.7	44.	0.0	0.0	43.	0.0	0.0
Isoperala	Riffle	31.	5.2	41.7	45.	0.0	0.0	44.	0.0	0.0
Psychodidae	Riffle	32.	4.2	33.3	46.	0.0	0.0	45.	0.0	0.0
Ithytrichia	Pool-U	33.	3.1	25.0	30.	4.6	41.7	24.	8.3	75.0
Leptophlebia	Pool-U	34.	3.1	25.0	14.	13.9	62.5	14.	14.8	66.7
Nematomorpha	Riffle	35.	3.1	25.0	47.	0.0	0.0	46.	0.0	0.0
Heptagenia	Pool-U	36.	2.1	16.7	36.	1.9	16.7	28.	5.6	50.7
Curculionidae	Riffle	37.	2.1	16.7	48.	0.0	0.0	47.	0.0	0.0
Acari	Riffle	28.	2.1	16.7	38.	0.9	8.3	48.	0.0	0.0
Acroneuria	Riffle	39.	2.1	16.7	49.	0.0	0.0	49.	0.0	0.0
Argia	Pool-U	40.	1.0	8.3	19.	11.1	33.3	12.	19.4	43.8
Polycentropus	Pool	41.	0.0	0.0	15.	12.0	21.7	5.	38.9	58.3
Helicopsyche	R-to-P	42.	0.0	0.0	33.	3.7	33.3	50.	0.0	0.0
Ptilostomis	Pool	43.	0.0	0.0	50.	0.0	0.0	29.	5.6	50.0
Palpomyia	Pool	44.	0.0	0.0	28.	6.5	58.3	30.	5.6	50.0
Tipula	R-to-P	45.	0.0	0.0	39.	0.9	8.3	51.	0.0	0.0
Stenonema	R-to-P	46.	0.0	0.0	23.	9.3	83.3	32.	1.9	16.7
Aeshna	Pool	47.	0.0	0.0	51.	0.0	0.0	27.	6.5	29.2
Ferrissia	Pool	48.	0.0	0.0	35.	2.8	25.0	25.	7.5	66.7
Pisidium	R-to-P	49.	0.0	0.0	27.	7.4	66.7	52.	0.0	0.0
Oligochaeta	Pool	50.	0.0	0.0	24.	9.3	75.0	9.	27.8	62.5
Sralis	Pool	51.	0.0	0.0	52.	0.0	0.0	15.	14.8	33.3
Paraleptophlebia	Pool	52.	0.0	0.0	31.	4.6	41.7	20.	10.2	45.8

*The "U" denotes the taxa that were found in all three habitats. I. R.: importance rank of each taxa in each habitat. S. A. and S. S.: importance values of the taxa on a study area basis and on a sampling site basis respectively.

nized in Table 28. Since the diversity levels of the macroinvertebrate associations did not markedly change from one habitat to another, the differences in faunal composition between the three locations can be best viewed as one of the replacement rather than one of elimination even though marked differences in abundance were also observed between the habitats.

The inter-habitat differences in importance values can also be used to classify the habitat preferences of the various macroinvertebrate taxa where a riffle taxa can be identified as those organisms that demonstrate a fairly consistent decrease in importance in moving from the riffle to the pool locations. The pool taxa in turn can be delineated on the basis of a fairly consistent increase in importance when moving in the same direction, and as a third category, the taxa that do not show any obvious trends of this kind can be classified as neutral in terms of their general habitat needs. In the case of the study area streams, 42% of the macroinvertebrates were observed to be riffle organisms, 33% were identified as pool organisms, and 17% were classified as neutral taxa on the basis of the above definition. In addition, a small number of the macroinvertebrates (8%) were recognized as riffle-to-pool animals because of their relatively high importance grading in this particular locale. But as a modifying comment, this classification scheme was not meant to present an "all-or-nothing" evaluation of the macroinvertebrates' physical requirements in terms of any habitat restrictions since many of the inventory taxa were collected from all three of the stream locations in varying levels of abundance. Rather, this categorization can only be used to pinpoint those habitats where the organisms can apparently assume a more dominant ecological role in the association under a particular set of environmental conditions.

The habitat preference ratings of the different macroinvertebrate taxa were also reflected in the compositional characteristics of the three general habitats under investigation as follows: of the twenty top-ranked organisms in the riffle location, eleven were identified as riffle taxa, six as neutral taxa, and three as pool taxa; of the twenty top-ranked organisms in the riffle-to-pool location, nine were recognized as riffle taxa, four as neutral taxa, and seven as pool taxa; and of the twenty top-ranked organisms in the pool location, only three were identified as riffle taxa while six were classified as neutral taxa and eleven as pool taxa. Thus, the importance assessment of this inventory appears to have provided for fairly consistent results in the sense of closely following the inter-habitat preference transitions that would have been initially visualized for a stream. The individual habitat preference of the fifty-two study area taxa that could be included into these analyses are listed in Table 28, and this table also denotes the more ubiquitous taxa that were found to be somewhat dominant in all three of the stream locations, at least with respect to some of the intensive sampling sites.

RESULTS AND DISCUSSION--POTENTIAL SALINITY EFFECTS

GROUPED DATA ANALYSES

Diversity Relationships

One of the major objectives of the inventory was to ascertain if salinity might have a major effect on the macroinvertebrate associations of the study area streams. Attention in these analyses was focused upon the diversity and total abundance aspects of these benthic communities, and such assessments were feasible in the context of the study since both diversity and total abundance along with salinity demonstrated fairly distinct differences among the project region waters. The proving and critical point of these evaluations was the demonstration that these inter-stream biotic and salinity variations were inversely related to each other to some extent, and this would imply that salinity was at least one of the affecting factors.

The initial approach that was used to illustrate and confirm the actuality of these biotic and salinity relationships involved a grouping of the sampling stations into three or four categories on the basis of their diversity (or abundance) levels, and this was followed by calculating the mean salinity concentrations of the streams in each of these diversity classes. If this water quality parameter did have a negative influence upon the macroinvertebrate associations that were collected from the various stations, then some corresponding, inverse, and fairly distinct differences in salinity would be expected to become evident among these categories. If this did not prove to be the case, then salinity could be largely discounted as an important water quality variable.

The first application of this kind was directed to the "low", "moderate", and "high" taxa richness-diversity categories in Table 10, and rather distinct differences in salinity were obtained between these classes where the thirteen streams in the high diversity grouping produced a mean specific conductance (SC) of only 1,135 micromhos per cm in contrast to the moderate and low diversity categories that produced much higher mean SC values of 2,580 and 3,215 micromhos respectively. A t-test of the difference in the mean salinity concentrations between the low and high diversity categories was found to be statistically significant at less than 1% with $t_{23} = 6.04$, and this result is indicative of a definite inverse relationship between salinity and diversity where the macroinvertebrate associations having the higher diversity and taxa richness characteristics were most typically collected from streams that had significantly lower salinity concentrations. Since physical factors such as stream size and intermittency have been largely eliminated as having an important influence on the macroinvertebrate diversity levels, these analyses suggest that salinity did play a significant role in producing the diversity differences that are evident among the project region sampling sites, although the action of other nonphysical and other physical factors cannot be totally ignored in this regard. The general success of this initial grouped data evaluation then provided the impetus for undertaking the more diagnostic and confirmatory but more involved correlation assessments that will be described later.

Another grouped data evaluation was directed to the Class A to D, biological quality-environmental stress categories that have been summarized in Table 20. The mean SC values that were obtained for these four classes can be listed as follows: Class A--1,130 micromhos, Class B--2,365 micromhos, Class C--2,909 micromhos, and Class D--2,243 micromhos. With the exception of the PR-Mz site in the Class D group whose macroinvertebrate association was apparently impacted by a non-salinity factor, i.e., by the high suspended sediment concentrations of the water, this assessment also produced an inverse relationship between salinity levels and the stress factor-biological health of the streams as judged by the magnitude of their Margalef and SW values. In other words, the moderately stressed biotic systems with their relatively low diversity levels were typically collected from the higher specific conductance waters as would be expected if salinity was actually operating as part of the environmental stress component that was affecting these macroinvertebrate associations. At the other pole, the unstressed, Class A streams with an excellent biological health had consistently much lower salinity levels than the Class C listings, and the mildly stressed Class B waters had somewhat intermediate SC values with reference to the Class A and C groups. These results also point to salinity as an influential factor with respect to the biological quality of the macroinvertebrate communities that inhabit the inventory region streams.

A one-way, completely random ANOVA of the SC values in the Class A, B, and C stream groupings was determined to be statistically significant at 2.5% with $F^{2}_{31} = 4.84$. A subsequent least significant difference multiple comparison (Lentner, 1969) indicated that the mean SC difference between Class A and Class C was statistically valid at less than 5% ($t_{31} = 3.06$), although the Class A to B and Class B to C comparisons could not be shown to be statistically significant through this same analysis.

The final grouped data application was directed towards an initial separation of the streams on the basis of salinity rather than diversity. It involved a segregation of the study area waters into two groups in relation to McKee and Wolf's (1963) instream biotic reference criteria for salinity which was set at 2,000 mg/l (generally equivalent to a SC value of 2,400 micromhos), and a similar segregation was completed in relation to the National Technical Advisory Committee (1968) criteria of 1,500 mg/l (roughly equivalent to a SC of 1,800 micromhos). Mean overall Margalef diversities were then determined for the macroinvertebrate associations in the streams with salinity levels greater than the published criteria and in the streams with salinity levels less than these standards as follows: mean $M_o = 1.42$ for SC's greater than 2,400, and mean $M_o = 1.92$ for SC's less than 2,400; mean $M_o = 1.46$ for SC's greater than 1,800, and mean $M_o = 2.09$ for SC's less than 1,800.

The results from these reference criteria evaluations also indicate the operation of a negative, salinity-related alteration of diversities in the project region waters. In addition, the 1,800 micromho criteria by the National Technical Advisory Committee appears to be most applicable of the two for judging the occurrence of a mild salinity stress in the streams since the diversity means above and below this value fell into the different A and B classes. In the case of 2,400 SC standard, however, both

of the means prescribed a Class B situation so that this SC value was too high to be utilized in this way. Furthermore, neither of these criteria are of any use for judging the occurrence of moderate or severe salinity stress since the lower M_O means in both instances was above the diversity value signifying a Class C situation. As a result, an appropriate reference criteria for diversity is probably someplace above a 2,400 SC value in the case of a moderately stressed environment and probably well above this salinity level for the development of a severe salinity impact on the macroinvertebrate associations, and these observations ultimately led to the completion of a parametric regression analysis as an approach for estimating these critical salinity levels.

Total Abundance Relationships

In contrast to the observation for diversity, the grouped data assessments of total station density did not demonstrate a distinct relationship between macroinvertebrate abundance and the salinity levels of the flowing waters in the study region. This lack of correlation can be generally illustrated through the application of a reference criteria evaluation to total abundance that is identical to the one that was applied to the diversity data. This analysis produced the following results: 9,168 individuals per square meter with SC's greater than 2,400 micromhos per cm, and 9,835 individuals per square meter with SC's less than 2,400 micromhos; 10,599 individuals per square meter with SC's greater than 1,800 micromhos, and 8,425 individuals per square meter with SC's less than 1,800 micromhos. These mean abundance differences between the high and low SC categories were found to be relatively small, inconsistent, and not statistically significant via a t-test.

Furthermore, an evaluation of the mean salinity levels associated with the streams that were included into the four "low," "moderate," "high," and "very high" density categories of Table 17 also failed to reveal any distinct and significant salinity-total abundance trends as follows: low abundance--2,369 micromhos, moderate abundance, 2,305 micromhos, high abundance--1,836 micromhos, and very high abundance--2,859 micromhos. The relatively small and inconsistent SC differences between these categories were also shown to be statistically insignificant through an ANOVA.

The results that were obtained from these grouped data assessments provide another example of the general independence of total abundance and diversity as biological variables in the inventory streams where the former was found to be unaffected by salinity variations within the range that characterized these waters; diversity was obviously influenced by this parameter to a fair degree. Also, physical alterations had a much greater influence on total abundance than they had on diversity. In essence, therefore, salinity appears to operate as a pollutant in the classical sense by lowering the diversity levels of the affected macroinvertebrate associations through a gradual elimination of some of the less tolerant organisms at the higher SC levels while not affecting the total abundance features of these communities to any significant extent. The elimination of the sensitive organisms sufficiently reduces biological competition so that the more tolerant organisms can increase in abundance and supplant those lost. As a result, the normal total abundance levels of the waters are maintained by this shift so that the salinity-density relationships cannot be recognized in the

total abundance evaluations. However, the abundance effects of salinity are probably reflected in the density data of the individual taxa, although no analyses along these lines were undertaken in this stage of the data assessments. Thus, other factors besides salinity must be operating to cause the total abundance variations that were observed among the study area streams. A listing of this kind would include the several physical features that were reviewed previously, and it could also include a fairly extensive set of various other physical, water quality, and biological parameters that will not be considered in this particular report.

CORRELATION AND REGRESSION ANALYSES

Diversity Relationships

Correlation assessments were directed to the SC and diversity-total density data of the inventory to confirm the results from the grouped data evaluations, i.e., to confirm the actual existence of an inverse relationship between salinity and the diversity characteristics of the macroinvertebrate associations, and its extent, and to confirm the absence of such a relationship with respect to total macroinvertebrate abundance. In addition, linear regression analyses were directed to these same data pairs in order to develop a quantitative expression that can be used for making specific predictions concerning the effect of differing salinity levels on the benthic faunal communities. These evaluations were completed on the following sets of data: the SC, total abundance, and Margalef diversity levels of all 191 of the natural substrate samples, and the mean SC, mean total abundance, and overall Margalef values that were calculated for the 35 sampling stations. Furthermore, SC and Margalef diversity correlations and regressions were also undertaken for the 75 individual samples that were secured via the artificial substrate collections as they were combined without regard to the separate habitats. A pooling of the artificial substrate samples was feasible in the case of diversity because no significant interhabitat differences could be identified for this variable. However, correlations and regression could not be directed to the total abundance levels of the artificial substrate collections since macroinvertebrate density was found to be habitat-dependent to a significant degree. The results that were obtained from each of these five statistical assessments are presented in Table 29.

All of the parametric correlation coefficients obtained from the diversity analyses were found to be negative and statistically significant at much less than 1% which tends to confirm the actuality of an inverse relationship between this biological variable and the salinity concentrations of the study area streams. This conclusion was further substantiated through the calculation of a rank correlation coefficient between the rankings of the sampling sites on the basis of their mean SC values and the stations' rankings relative to their mean diversity levels. A statistically significant (less than 1%) and negative coefficient of $r_s = -0.69$ was also computed from this evaluation.

The y-intercept and slope values that were obtained from the mean station and the individual sample regressions between SC and natural substrate diver-

Table 29. Results from the correlation and regression analyses between the salinity levels of the study area streams as specific conductance (SC in micromhos per cm at 25C) and the corresponding total abundance (A) and Margalef (M_o) diversity values of their benthic macroinvertebrate associations. An n denotes the number of pairs in each evaluation.

<u>Diversity (all natural substrate samples) (n = 191)</u>

Correlation: r = -0.34, significant at less than 1%

Linear Regressions*: $M_o = -0.00018SC + 2.28$

<u>Diversity (station means from natural substrate samples) (n = 35)</u>

Correlation: r = -0.46, significant at less than 1%

Linear Regression*: $M_o = -0.00020SC + 2.21$

<u>Diversity (all artificial substrate samples--pooled) (n = 75)</u>

Correlation: r = -0.44, significant at less than 1%

Linear Regression*: $M_o = -0.00029SC + 2.51$

<u>Total Abundance (all natural substrate samples) (n = 191)</u>

Correlation: r = -0.01, insignificant at 10%

Linear Regression*: $A = -0.0128SC + 1095$

<u>Total Abundance (station means from natural substrate samples) (n = 35)</u>

Correlation: r = -0.06, insignificant at 10%

Linear Regression*: $A = -0.0374SC + 949$

*Linear regression equation in the form of $y = mx + b$ with m representing the slope and b the y-intercept; $M_o = mSC + M_{ob}$ for diversity, and $A = mSC + A_b$ for total abundance.

sity were observed to be fairly similar, and as indicated in Table 29, these y-intercepts indicate that a typical Margalef index of about 2.25 units at the taxonomic resolution capabilities of the inventory might be generally expected from those streams that are not facing any marked salinity stress at low SC levels. The slopes of the natural substrate regression equations, in turn, suggests that diversities might be expected to decline by about 0.2 of a Margalef unit for each 1,000 micromho increase in salinity as SC. As a result, extremely low macroinvertebrate diversities near zero would probably be observed for the waters as salinity concentrations approach 12,000 micromhos which is beyond the natural range of lotic salinities in the coalfield area.

The following SC values were obtained from the natural substrate regression equations with reference to the Class A to D, environmental stress and biological quality categories in Table 20 and the associated diversity guidelines: the Class A group (no environmental stress with an excellent biological health) with Margalef diversities at the taxonomic capacities of the study greater than 2.00 would have corresponding SC salinity levels at less than 1,325 micromhos and approaching zero micromhos; the Class B group (a mild environmental stress with a good biological health) with Margalef diversities between 1.35 and 2.00 would have corresponding SC salinity levels between 1,325 and 4,750 micromhos; the Class C group (a moderate environmental stress with a fair biological health) with Margalef diversities between 0.67 and 1.35 would have corresponding SC salinity levels between 4,750 and 8,325 micromhos; and the Class D group (a severe environmental stress with a poor biological health) with Margalef diversities at less than 0.67 would have corresponding SC salinity levels greater than 8,325 and approaching 12,000 micromhos. As an extension of this classification, macroinvertebrate associations of the kind that have been identified for the project region streams would not be anticipated for lotic waters with SC salinity concentrations much beyond 12,000 micromhos.

The SC values that are listed in the previous paragraph can be construed as salinity reference criteria that describe the critical levels of specific conductance in relation to the different biological quality and health stages of the streams as diagnosed by the diversity characteristics of their macroinvertebrate associations. As suggested in Table 29, a slightly different set of Class A to D SC values would be calculated from the regression equation that was developed from the artificial substrate data than from the equations that were obtained from the natural substrate work because of the higher slope in the former case. These discrepancies are probably a reflection of the somewhat different systems that were assessed in the two separate macroinvertebrate phases of the project with the artificial substrate sampling directed to a smaller set of streams while using a different collection procedure. Thus these types of statistical evaluations appear to be system-dependent to some degree, and since the Surber efforts involved a wider selection of streams and samples with sampling directed to the natural stream bottom materials, it is felt that the regression analyses from the Surber segment of the inventory are most representative of the actual conditions in the study region. Therefore, further salinity interpretations will be based on the natural substrate regression equations. But in any event, the differences between the natural and artificial substrate regressions, on the order of 25%, are not all that great in view of the general kinds of interpretations that are to

be made for the study.

As suggested by the natural substrate regression evaluations of this inventory, if a stream has inherent salinity concentrations that are less than 1,325 micromhos, enhancements of this water quality parameter should not be allowed that would elevate the SC levels of the water much above the 1,200 level if the excellent biological health characteristics of the water are to be preserved. However, if a mild degree of stress is acceptable in relation to the aesthetic value of the stream, then salinity increases to around 4,000 micromhos for the Class A and B streams in Table 20 can probably be tolerated while still maintaining a fairly good biological quality. But salinities should definitely not be increased beyond a 4,500 micromho level in these low salinity waters if a moderate biological degradation is to be avoided with respect to their benthic macroinvertebrate communities.

The low salinity streams of the study region, therefore, do have a biological buffering capacity that is inversely proportional to the natural salinity concentrations of the water. But for Class C streams showing a moderate salinity degradation from natural sources with SC's greater than 4,750 micromhos, this buffering capability is largely delimited, and in this case, any increase in salinity will cause a further reduction in their already marginal biological qualities. According to the regression equation, some biotic degradation will occur in all cases of significant salinity elevations, but it is much more intensified in the high SC streams that have only a fair and already marginal biological health. In these instances, further salinity increases should be avoided, and they definitely should not be elevated much beyond an 8,000 micromho value if a severe biological degradation is to be avoided in the water's faunal communities. The high salinity and severely stressed streams with SC values naturally greater than 8,500 micromhos, on the other hand, already possess a relatively poor biological quality, so further salinity impacts in these situations are probably not too critical, dependent upon a person's point of view. However, none of the study area waters fall into this Class D category because of a salinity effect, and the marginal Class C waters of the region are listed in Table 20.

The above discussion delineates rather broad SC reference criteria that can be used to diagnose the current biological-benthic status of a stream, to assess the critical nature of a water's present salinity concentrations, and to ascertain what salinity increases might be tolerated by the stream without a significant lowering of its biological health characteristics. Salinity elevations across these SC guidelines should be avoided as an initial restriction if the general biological qualities of the streams are to be maintained, and the inherent salinity concentrations of a flowing water become more important in this regard, and in relation to biological degradation, as they fall closer to the high SC endpoints of each of the four, Class A to D categories. But between these wide endpoints, the significance of a slight reduction in macroinvertebrate diversity from the perspective of degradation (e.g., from 1.85 to 1.75) as a result of a small elevation of salinity (i.e., 500 micromhos) becomes a matter of conjecture that cannot be resolved in the context of this study.

The State of Montana has adopted a nondegradation policy as part of its Water Quality Act (Sec. 75-5-303, M.C.A. 1979) which indicates that any increase in salinity could be viewed as a degradation through a lowering of the streams' benthic diversity levels to some extent. "In effect, this policy would prevent a developer from increasing the salinity level of a state water, except in the case of a successful appeal to the Board of Health and Environmental Sciences, and then only if the increase does not preclude present and anticipated beneficial uses (Bahls, 1980)." Thus, this Board would have the authority to judge, on the basis of the results of this study, if any given decrease in macroinvertebrate diversity that is produced by a particular salinity impact is sufficient to be classified as degrading to the beneficial uses of the stream, with the maintenance of the water's benthic biota considered to a beneficial in-stream use of the water.

Abundance Relationships

In contrast to the observations for diversity, the correlation coefficients obtained from the total abundance-specific conductance analyses were extremely small and insignificant statistically (Table 29) which points to the absence of distinct relationship between total macroinvertebrate density and salinity within the ranges of SC that characterize the study area streams. If the slope and y-intercepts regression constants for abundance are assumed to be valid, then salinity concentrations on the order of 10,000 micromhos would be required to reduce total density levels by only 10%. Therefore, other environmental factors besides salinity must be affecting the benthic density features of the different inventory streams. This observation then provides a steppingstone for a further statistical evaluation of the inventory data to ascertain which of the potential factors might have an influence on this biotic variable and to what degree.

In a similar vein, the relative low diversity correlation coefficients that were obtained from this initial assessment provided a coefficient of determination (r^2) that indicates that only about 12% to 21% of the benthic diversity variations in the study area streams were accountable to the associated variations in the streams' salinity levels. As a result, other factors in addition to salinity, including a random variability component, must also be exerting an influence on macroinvertebrate diversity. Further statistical analyses, therefore, could also be made in this direction through the use of a multiple regression approach or by applying some more sophisticated technique. Furthermore, attention could also be focused upon the effect of salinity and the other environmental factors on the abundance levels of the individual taxa. Of importance to these considerations is the fact that the requisite data base is now at hand as a result of the coalfield inventory from which to make these additional assessments.

SYNOPSIS

The southern Fort Union region in southeastern Montana contains large quantities of strippable coal deposits, and because of the nation's large energy demand, this particular area will probably be the center of intense coal mining activities in future years. A number of streams of varying

sizes and with different flow characteristics interlace these coalfields, and these waters will be influenced to some extent by the water quality impacts, including elevated salinity concentrations, that are originated with the coal removal efforts in their drainages. In light of this prediction, a biological-benthic inventory was conducted on a number of the streams in this southern Fort Union region to varying degrees of intensity in order to obtain a core of baseline data that describe the predevelopment characteristics of their biological communities; these data will also then be available for comparative purposes as mining proceeds in the area. Attention was focused primarily upon the benthic macroinvertebrate associations, the periphyton communities, and the macroalgae organisms that are found in the inventory streams, and Bahls (1980) has presented the results of the algal assessments. This report has been directed to the faunal components of the streams, and one objective of this writing involves a description of the community structure, faunal composition, and general characteristics of these particular animals. As a corollary objective, an effort was to be made to ascertain the potential action of salinity as an affecting factor on these macroinvertebrate associations. A companion data report (Klarich, et al, 1980) presents most of the faunal, algal, water quality and physical information that were collected during the project.

APPENDIX

Table 30. Macroinvertebrate taxa with specimens included into the project's permanent reference collection.

COL:	Carabidae
	Curculionidae
	Hyperodes
	Listronotus
	Helichus
	Agabus
	Deronectes
	Dubiraphia
	Microcylloepus sp.
	Microcylloepus pusillus
	Optioservus divergens
	Optioservus quadrimaculatus
	Stenelmis sinuata
	Stenelmis vittipennis
	Zaitzevia parvula
	Haliplus
	Heteroceridae
	Hydrophilidae
	Berosus
	Enochrus
	Helophorus
	Hydrochus
	Laccobius
	Ochthebius
	Gyrinis-*Gyretes* complex
	Limnichidae
DIP:	Brachycera
	Dalichopodidae
	Clinocera-*Chelifera* complex
	Hemerodromia
	Euparyphus
	Nemotelus
	Odontomyia
	Stratiomys
	Tabanidae
	Chrysops
	Muscidae
	Limnophora
	Scatophagidae
	Chironomidae
	Dixidae
DIP:	*Bezzia*-*Probezzia*-*Palpomyia* *complex*
	Palpomyia
	Culicoides
	Psychodidae
	Pericoma
	Simulium
	Tipulidae
	Dicranota
	Pseudolimnophilia
	Tipula
EPH:	*Baetis*
	Pseudocloeon
	Caenis
	Ephemera
	Heptageniidae
	Rhithrogena
	Stenonema
	Leptophlebiidae
	Choroterpes
	Leptophlebia
	Paraleptophlebia
	Ephoron
	Siphlonurus
	Tricorythodes
HEM:	Corixidae
	Hesperocorixa
	Sigara
	Trichocorixa
LEP:	*Parargyractis*
MEG:	Sialidae
	Sialis
	Dysmicohermes
ANI:	*Aeshna*
	Gomphidae
	Gomphus
	Ophiogomphus
	Libellulidae
	Leucorrhinia
ZYG:	*Hetaerina*
	Argia
	Ischnura
PLE:	Nemouridae
	Nemoura
	Acroneuria
	Perlodidae
	Isoperla
TRI:	Brachycentridae
	Brachycentrus
	Glossosomatidae
	Culoptila
	Helicopsyche
	Cheumatopsyche
	Hydropsyche
	Potamyia
	Hydroptila
	Ithytrichia
	Ochrotrichia
	Leptoceridae
	Nectopsyche
	Oecetis
	Limnephilidae
	Anabolia
	Glyphopsyche
	Hesperophylax
	Limnephilus
	Onocosmoecus
	Ptilostomis
	Nyctiophylax
	Polycentropus
OST:	Ostracoda
AMP:	*Gammarus*
ACA:	Acari
HIR:	*Percymoorensis marmoratis*
	Erpobdellidae
	Dina anoculata
	Glossiphoniidae
	Batracobdella
	Glossiphonia
	Helobdella
	Placobdella
OLI:	Oligochaeta
GAS:	*Ferrissia*
	Lymnaea
	Gyraulus
	Helisoma
	Physa
	Columnella
PEL:	*Pisidium*
	Sphaerium
TUR:	Turbellaria
NMT:	Nematomorpha

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